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PROCEEDINGS

OF THE

ROYAL PHYSICAL SOCIETY.

SESSION CXXVII.

Wednesday, 17th November 1897.—Professor J. STRUTHERS, M.D., LL.D., President, in the Chair.

The President delivered the opening address, entitled "Rudimentary Structures and their Meaning, in Man and in certain Animals."

The publication of this address is unavoidably postponed.

I. *Results of Meteorological Observations taken in Edinburgh during* 1897. By R. C. MOSSMAN, F.R.S.E., F.R.Met.Soc.

(Read 19th January 1898. Published 4th April 1898.)

The data discussed in this paper are deduced from eye-observations of the standard instruments read daily at 9 A.M. and 9 P.M. Automatic methods of registration yield continuous traces of the fluctuations in pressure, temperature, humidity, rain, and sunshine. It is with much regret that I find myself still unable to cope with the task of reducing these records. Hourly values of sunshine have been tabulated, but the preparation of similar values for the other elements was found on trial to be impracticable. The

detailed weekly and monthly reports—140 in number—continue to be sent to the Scottish Meteorological Society, the Registrar-General for Scotland, and the Meteorological Office. The long averages with which the mean monthly values are compared will be found in Part II. of my paper on "The Meteorology of Edinburgh."[1] As it is some years since any account of the instruments has been given, the following particulars may be of interest.

Position of Station.—The observing station is situated in the Newington district of Edinburgh, the general height of the ground being 250 feet above mean sea-level. The position is open, and the air circulation remarkably true, the only disturbing factor being exerted by the high ground of Arthur's Seat (822 feet), about one mile to the east. During the thirty years preceding the establishment of this station in 1886, the observations were made within a mile of the present site, and for many years within 200 yards.

Barometers.—The standard barometer is on the Fortin principle, and has a tube six-tenths of an inch in diameter. It has a Kew certificate. A spare Board of Trade barometer is used as a check. There are two barographs, one an elaborate mercurial instrument by Redier of Paris, the other being one of the well-known Richard aneroidographs. The paper to receive the registrations is coiled around revolving cylinders driven by clockwork. The sheets are changed every week. There is also a long range Watkin aneroid, which has been found remarkably correct.

Thermometers and Hygrometers.—The maximum and minimum thermometers are exposed along with the dry and wet bulb thermometers in a Stevenson's thermometer screen placed over a grass plot. Another but larger screen contains a Richard thermograph and a hygrograph by the same makers. These instruments give traces of thermometric and hygrometric fluctuations respectively. A black bulb maximum solar radiation thermometer is freely exposed at a height of 4 feet above the ground, and a terrestrial minimum is placed on the surface of the ground. Earth thermometers, with their bulbs buried in ordinary garden

[1] *Trans. Roy. Soc. Edin.*, vol. xxxix. pp. 63-207.

mould, are placed at depths of 3, 12, and 22 inches under short grass. A number of spare thermometers are kept in reserve.

Rain Gauges.—The standard gauge is of copper, and is 5 inches in diameter. The height of the rim above sea-level is 254 feet. One of Symon's storm rain gauges is employed for the measurement of thunderstorm and other torrential rains. During the last four years a Richard self-registering rain gauge has given a continuous record during eight months of the year. It is taken indoors during the winter season, as it is liable to sustain damage during frost.

Sunshine.—A Campbell-Stokes sunshine recorder is employed for the determination of bright sunshine. Its position has to be changed three times a year, in order that it may have the benefit of a clear horizon.

Wind.—A Robinson hemispherical cup anemometer is placed on the top of a ladder erection 17 feet above the ground. It is read daily at 9 A.M., except when snow or hoar-frost has been deposited on the steps. When this is the case no reading is made, as the risk in ascending is considerable.

Rainband.—Observations of the thickness of the rainband in the spectrum of sunlight have been made three or four times daily during the last ten years. No observations are made during the author's absence from home, as the work cannot conveniently be handed over to the interim observer.

I take this opportunity of acknowledging my indebtedness to Mr W. M. Mossman, who observes in my absence, thus enabling an unbroken record to be maintained during the past eleven years.

Remarks on the Meteorology of 1897.

January.—Cold, dry, and dull weather prevailed during the whole month. The absolute maximum was 47°·0 on the 4th, there being only four Januarys during the last fifty-seven with a lower absolute value. From the 9th till the end of the month, frost was recorded nearly every night. During this time the highest temperature recorded was 39°·8, on the

24th, and the lowest 20°·8, on the 25th. Owing to the cloudy skies, the solar radiation maximum was never much above the corresponding shade value. Only 24 hours sunshine was recorded. The precipitation, chiefly in the form of snow, was under an inch. There was a fog on the 10th and 11th.

February.—The cold weather of January continued to prevail during the first twelve days of February, but the depression of temperature was more apparent in the day than in the night values, the diurnal range being thus very small. The second half of the month was mild and stormy, with a good deal of rain during the last week. During the last fortnight the weather was sunny. A strong gale blew on the 25th, on which evening, at 9 P.M., the sky was cloudless, but the air was saturated, rain falling heavily. No frost was registered after the 12th.

March.—Very unsettled stormy weather prevailed throughout March, with little frost. The mean barometric pressure was only 29·481 inches, the lowest since February 1885, while there were only three months since 1769 with a lower value. Only for a few hours on the 7th and 8th did the sea-level pressure exceed 30 inches. The winds were almost wholly from the south and west. Rain fell on 24 days, the only really fine day being the 29th. Snow fell on the 4th, 10th, 28th, 30th, and 31st, but did not lie on the ground, the temperature of which was high.

April.—The weather of April was cold, dry, and, comparatively speaking, sunless. The mean temperature was only 42°·6, the lowest since 1886, and the highest temperature recorded 57°·3, the lowest absolute maximum since 1879. At no time during the month was anything like spring weather experienced, for although no frost was registered after the 8th, the cold, humid winds off the North Sea made conditions exceedingly trying. There was a fog on the 8th, and snow fell on the 14th.

May.—The characteristic features of the weather of May were a low mean temperature, small rainfall, and excess of sunshine. There was again a deficit of warmth, the absolute maximum of 67°·9 being one of the lowest May maximums

during recent years. Rainfall was only half the average, the fall being entirely confined to the first and last weeks. No measurable quantity fell from the 8th to the 23rd inclusive. The ground remained very cold till the middle of the month, the 22-inch earth thermometer rising only half a degree between the 1st and 15th. Fogs occurred on the 20th, 27th, and 28th.

June.—The weather experienced this month was of a phenomenal character, the mean temperature of the month being the lowest since 1888, the rainfall larger than in any June since 1879, and the mean daily variability of temperature greater than in any month during the last fifty-seven years, with the single exception of November 1847, which had a variability 0°·2 greater. The amount of cloud was singularly large, only 83 hours bright sunshine being recorded, which was lower than in any June since 1863. The winds during the month blew persistently from the east, and, in spite of a high barometer, the air was very raw and humid. Fine weather was almost wholly absent, only two days, the 5th and 25th, having more than half the total possible sunshine, while there were eleven sunless days. During the first twelve days little rain fell, only 0·28 inch being recorded. During this time the temperature was on the whole low, with a small diurnal range, the result of densely overcast skies. The mean temperature on the 8th was as low as 43°·8, the minimum being 36°. Very wet weather prevailed from the 13th to the 19th, no less than 3·27 inches falling. The mean temperature on several days was very low, notably on the 18th, 19th, 20th, with values of 45°·6, 49°·1, and 45°·5 respectively. The 16th was also a notable day, the temperature falling from 52°·5 at 9 A.M. to 43°·4 at 2.30 P.M., this being the lowest for the day, and 20°·5 below the average maximum for the time of year. At 10 A.M. 0·44 inch of rain fell in sixteen minutes. The last ten days of the month were showery, but the temperature was in excess of the normal. The inclement weather materially retarded the growth of plants, the temperatures of the soil at depths of 12 and 22 inches being exactly seven weeks behind 1896. The 12-inch thermometer on the morning of the 21st

indicated a temperature of 51°·3, a reading equalled last year (1896) on May 6, while the 22-inch thermometer read 51°·0, which was passed in 1896 on May 9. With the close of June terminated the long period of deficient sunshine, only 712 hours, or one-fifth of the possible, having been recorded since the beginning of September 1896. During the last four months of 1896 the sun shone for only 150 hours, and of the 562 hours recorded during the first half of this year, April and May had 330. There were hardly any fine days in the period under review, 104, or one-third, having no sunshine, while 94 of the days on which the sun shone had less than 20 per cent. of the total possible. Only one day in nine during the period under review had more than half the possible, and there were only nine days with more than 70 per cent. of the total possible sunshine.

July.—The weather of July was unusually fine and warm, especially during the first eighteen days. The conditions during this time were exceptionally brilliant, the sunshine recorder showing a total of 153 hours; the greatest previously registered for the period since the record commenced in 1861 being 139 hours, in 1876. The rainfall for the first eighteen days was only 0·15 inch, the lowest since 1869. The mean temperature for the whole month, 59°·2, was the highest since 1887, while the amount of bright sunshine, 232 hours, was the greatest since 1885. Unusual nocturnal warmth prevailed on the night of the 23rd to 24th, the minimum recorded being 61°·4. During the last fifty-seven years only ten warmer nights have been experienced.[1] No rain fell from the 9th to the 18th inclusive.

August. — Although a good deal of rain — principally thunderstorm—fell, the weather of August was both warmer and sunnier than usual. Very warm weather prevailed during the first twelve days, the mean of the maxima being 71°·9, and of the minimum 55°·3, these values being respectively 6°·3 and 4°·5 above the average for the period under review. A good deal of rain fell during thunderstorms, which were rather frequent during the first eleven days. Mean pressure was the lowest, with one exception (1891),

[1] *Trans. Roy. Soc. Edin.*, vol. xxxix. p. 134.

during the last twenty years. The only anti-cyclone experience occurred on the first four days of the month.

September.—The weather this month presented few features of interest, most of the elements approximating closely to their normals. The most noticeable feature was the scanty precipitation, namely, 1·64 inch. More than half the month's rainfall fell in the first four days, which were cold and stormy. There was no pronounced spell of fine sunny weather, but, on the other hand, no really unseasonable weather was experienced. During the last week strong westerly winds prevailed, which attained the strength of a gale on the 25th.

October.—Very high pressure prevailed during nearly the whole month, the mean of 30·106 inches being the highest since 1866. Mild weather predominated, the mean temperature being 2 degrees above the average. The excess was largely due to the high day temperatures, which culminated on the 21st in a value of 64°·3, which is the highest on record so late in the season during the last fifty-seven years. Cold weather prevailed on the 14th, on which day the mean temperature was only 36°·2, but on the 17th the mean had risen to 57°·8. The average temperature of the week ending 22nd October was 54°·4, or 7°·7 in excess of the normal. Very foggy weather was experienced during the last ten days, no less than six of which were foggy. October 1827 had also six fogs, the maximum being seven fogs in October 1786.

November.—This was a very mild month, the mean temperature being 45°·6, a value exceeded only in the Novembers of 1818, 1881, and 1894, with mean temperatures of 46°·7, 46°·3, and 46°·0 respectively. The excess was largely brought about by the remarkable nocturnal warmth, the mean of the day values being 2°·6, but the night values as much as 5°·3 in excess of the normal. The mean of the minima was 41°·8, the highest since 1857, when the average was 41°·9. The barometric pressure was 0·295 inch in excess of the normal. The only Novembers since 1770 with so high a pressure were 1805, 1857, 1867, 1879, and 1896. A dense fog was experienced on the 11th, which was

followed by a N.E. wind on the 14th with snow and hail. A strong gale with sleet and snow occurred on the 28th, the month closing with a temperature below the average.

December.—During December most of the meteorological elements approximated closely to their normals, the most noticeable feature being the dense fogs which accompanied the cold weather from the 18th to the 25th. The maximum barometric pressure for the year occurred on the 21st, and was soon followed by the minimum for the year, on the 30th. Although little sunshine was recorded, there were never more than three consecutive days without any. Snow fell on the 1st and 8th, but the month, as a whole, was mild and open, presenting little appearance of winter. The wind blew almost wholly from the west and south-west.

NOTEWORTHY PHENOMENA IN THE METEOROLOGY OF 1897.

Highest barometric reading 30·653 inches, on December 21st, at 8 A.M.

Lowest barometric reading 28·685 inches, on December 30th, at 10 A.M.

Highest temperature in shade 81°·0, on July 15th.

Lowest temperature in shade 20°·8, on January 25th.

Greatest range of temperature 31°·7, on July 15th.

Least range of temperature 2°·3, on November 5th.

Highest temperature in sun's rays (black bulb thermometer in *vacuo*) 131°·2, on June 12th.

Greatest excess of sun maximum over shade maximum 66°·0, on April 4th.

Lowest temperature on grass 18°·1, on January 25th.

Greatest difference between minimum on grass and in shade 9°·4, on December 2nd.

Sunniest day May 17th, with 14 hours 30 minutes bright sunshine, being 88 per cent. of the total possible.

Greatest daily rainfall 1·00 inch, on June 3rd.

	Barometer at 32° and Mean Sea-Level.						Temperature in Shade 4 Feet above Grass.															
																	Departure from Average 50 years.					
	Highest in Month.	Lowest in Month.	Monthly Range.	Difference from Average 1840–1896.	Mean Pressure.	Difference from Average 1770–1896.	Highest in Month.	Lowest in Month.	Range.	Mean Temperature.	Mean of all the Highest.	Mean of all the Lowest.	Mean Daily Range.	Greatest Daily Range.	Least Daily Range.	Mean Variability of Temperature.	Mean Max.	Mean Min.	Mean Daily Range.	Mean Temp.	Mean Variability of Temp 57 years.	Diff. from Aver. 1764-1896, Mean Temp.
	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°
January,	30·413	29·268	1·145	− ·406	29·933	+ ·115	47·0	20·8	26·2	35·0	38·7	31·3	7·4	18·1	2·6	2·2	− 4·0	− 1·5	− 2·5	− 2·8	− 1·0	− 1·8
February,	30·426	29·328	1·098	− ·339	29·938	+ ·125	56·1	28·2	27·9	41·4	45·6	37·1	8·5	14·3	3·0	2·3	+ 1·3	+ 3·3	− 2·0	+ 2·3	− 0·6	+ 3·1
March,	30·112	28·703	1·409	− ·009	29·482	− ·382	56·0	26·7	29·3	41·8	46·8	36·8	10·0	16·5	5·2	2·3	− 0·1	+ 2·4	− 2·5	+ 1·2	− 0·5	+ 1·5
April,	30·363	29·256	1·107	− ·103	29·837	− ·058	57·3	26·4	30·9	42·6	49·5	35·8	13·7	22·9	6·8	2·4	− 2·5	− 1·8	− 0·7	− 2·2	− 0·3	− 2·2
May,	30·515	29·226	1·289	+ ·212	29·949	+ ·009	67·9	33·9	34·0	48·2	55·5	40·8	14·7	23·0	4·3	2·5	− 2·1	− 1·3	− 0·8	− 1·7	− 0·3	− 1·7
June,	30·287	29·280	1·007	+ ·072	30·007	+ ·075	73·4	36·0	37·4	54·1	60·6	47·6	13·0	24·0	3·8	4·7	− 3·0	− 0·2	− 2·8	− 1·6	+ 1·9	− 1·6
July,	30·370	29·374	0·996	+ ·061	29·961	+ ·085	81·0	43·3	37·7	59·2	67·2	51·1	16·1	31·7	3·3	3·5	+ 1·6	+ 0·5	+ 1·1	+ 1·1	+ 1·0	+ 0·6
August,	30·254	29·223	1·031	+ ·032	29·696	− ·179	78·1	48·6	29·5	60·4	67·9	53·0	14·9	23·5	7·8	1·9	+ 2·9	+ 2·7	− 0·2	+ 2·8	− 0·6	+ 2·6
September,	30·551	29·322	1·229	+ ·056	29·898	+ ·024	69·1	38·0	31·1	53·0	60·7	45·4	15·3	23·8	6·0	2·3	− 0·3	− 1·6	+ 1·3	− 1·0	− 0·3	− 0·6
October,	30·600	29·198	1·402	− ·079	30·106	+ ·296	64·3	29·7	34·6	49·2	56·0	42·4	13·6	21·4	4·6	2·8	+ 2·9	+ 1·0	+ 1·9	+ 2·0	− 0·1	+ 2·0
November,	30·606	28·803	1·803	+ ·237	30·101	+ ·300	57·3	27·3	30·0	45·6	49·4	41·8	7·6	17·3	2·3	2·9	+ 2·6	+ 5·3	− 2·7	+ 3·6	− 0·2	+ 4·7
December,	30·653	28·685	1·968	+ ·410	29·724	− ·076	54·0	24·9	29·1	39·8	44·5	35·2	9·3	16·6	3·4	3·7	+ 0·7	+ 1·1	− 0·4	+ 0·9	+ 0·5	+ 1·5
Year,	30·653	28·685	1·968	...	29·886	+ ·028	81·0	20·8	60·2	47·5	53·5	41·5	12·0	31·7	2·3	2·8	0·0	+ 0·8	− 0·8	+ 0·4	0·0	+ 0·7

	Rainfall.					Relative Humidity. Saturation=100.				Vapour Pressure.			Solar and Terrestrial Radiation.							
	Total Fall.	Max. in 24 hours.	Diff. from Average 121 years.	No. of days on which ·01 in. or more fell.	Diff. from Average 1877–1896.	At 9 A.M.	At 9 P.M.	Mean.	Diff. from Average.	At 9 A.M.	At 9 P.M.	Mean.	Maximum in Sun.	Mean.	Greatest Excess over Shade Maximum.	Average Excess over Shade Maximum.	Minimum on Grass.	Mean.	Greatest Difference from Shade Min.	Mean Difference from Shade Min.
	Ins.	Ins.	Ins.	Days.	Days.	%	%	%	%	In.	In.	In.	°	°	°	°	°	°	°	°
January, . . .	0·80	0·22	− 1·67	10	− 6	83·7	81·9	82·8	− 4·0	·172	·172	·172	73·8	53·1	38·4	18·1	18·1	27·4	6·5	3·9
February, . .	1·42	0·56	− 0·55	13	− 1	83·2	85·8	84·5	− 1·9	·219	·226	·222	104·2	69·3	51·3	23·7	22·5	33·3	7·2	3·8
March, . . .	2·87	0·60	+ 0·90	24	+ 9	81·8	81·4	81·6	− 2·5	·212	·211	·212	107·3	86·1	51·8	39·3	20·5	33·9	9·3	2·9
April, . . .	1·04	0·33	− 1·02	13	− 1	75·2	82·3	78·8	− 1·7	·217	·215	·216	113·7	96·5	66·0	47·0	21·5	32·0	6·3	3·8
May, ...	1·28	0·40	− 0·81	14	0	77·5	81·3	79·4	+ 1·3	·258	·245	·251	127·7	104·1	62·1	48·6	26·3	37·8	7·6	3·0
June, . . .	3·99	1·00	+ 1·89	21	+ 7	82·2	85·6	83·9	+ 6·5	·360	·341	·351	131·2	103·6	62·5	43·0	32·3	46·1	6·7	1·5
July, ...	1·82	0·71	− 1·54	10	− 8	71·7	83·4	77·6	− 1·5	·380	·372	·376	130·7	116·5	58·4	49·3	40·1	49·4	3·9	1·7
August, . . .	4·24	0·99	+ 0·76	19	0	79·2	85·5	82·4	+ 0·9	·422	·416	·419	129·1	115·3	60·5	47·4	44·5	51·1	4·6	1·9
September, . .	1·64	0·33	− 1·28	20	+ 4	82·4	85·7	84·0	+ 1·4	·339	·315	·327	113·3	100·6	54·0	39·9	34·0	42·7	5·6	2·7
October, . . .	1·27	0·48	− 1·13	10	− 7	88·0	87·8	87·9	+ 2·1	·298	·297	·298	108·2	87·7	48·6	31·7	23·5	38·3	6·2	4·1
November, . .	1·97	0·41	− 0·67	16	− 1	89·2	87·1	88·2	+ 1·4	·282	·269	·276	79·0	62·5	36·6	13·1	22·3	39·4	5·8	2·4
December, . .	2·45	0·39	− 0·03	15	− 1	86·8	84·9	85·8	− 0·6	·216	·216	·216	69·9	54·6	25·4	10·1	20·5	31·5	9·4	3·7
Year, ...	24·77	1·00	− 5·10	185	− 5	81·7	84·4	83·0	0·0	·281	·275	·278	131·2	87·5	66·0	34·0	18·1	38·7	9·4	2·8

	Bright Sunshine for Hour ending Greenwich Time.																						Cloud 0–10.			Horizontal Air Movement.		
	A.M.								P.M.																		
	5	6	7	8	9	10	11	Noon.	1	2	3	4	5	6	7	8	Total.	Percentage of possible Duration.	Difference from Average 30 years.	Greatest Percentage of possible in 1 Day.	No. of Sunless Days.	Difference from Average 30 years.	9 A.M.	9 P.M.	Mean.	Total Movements.	Mean Velocity per hour.	Estimated Wind Force, 0–12.
	Hrs.	Hrs.	Hrs.	Hrs.	Hrs.	Hrs.	Hrs.	Hrs.	Hrs.	Hrs.	Hrs.	Hrs.	Hrs.	Hrs.	Hrs.	Hrs.	Hrs.	%	%	%						Mls.	Mls.	
January, . .	...	...	...	...	...	0·4	5·5	5·1	3·9	5·0	3·6	0·5	...	...	...	...	24·0	10	−11	47	13	+ 2	8·1	7·2	7·6	3687	5·0	0·74
February, .	...	...	...	0·3	2·2	5·9	7·4	8·0	7·5	6·2	6·4	2·6	0·1	...	...	...	46·6	18	− 8	53	11	+ 6	8·3	6·0	7·2	4861	7·2	1·09
March, . .	...	...	2·2	4·4	7·2	8·2	9·3	8·3	8·6	8·1	8·0	7·7	5·3	0·7	...	...	78·0	21	− 9	79	4	− 3	7·7	6·0	6·8	5824	7·8	1·23
April, . . .	...	...	2·9	7·4	7·2	12·1	12·9	13·4	13·3	11·7	12·3	10·3	11·2	9·5	3·4	0·4	128·0	30	0	72	3	− 2	7·0	6·9	7·0	3948	5·5	0·94
May, . . .	0·4	7·1	10·6	12·3	13·0	14·7	15·8	16·4	17·3	17·8	16·2	15·9	15·5	14·0	11·7	3·2	201·9	40	+ 8	88	3	− 1	7·9	5·5	6·7	4892	6·6	0·88
June, . . .	0·9	2·8	2·6	4·5	3·8	6·0	5·4	6·2	6·9	7·8	9·7	6·6	6·7	7·4	4·9	0·9	83·1	16	−12	64	11	+ 8	9·1	8·5	8·8	2625	3·6	0·73
July, . . .	3·2	12·1	13·7	15·8	17·1	17·3	20·0	20·0	18·9	17·2	16·8	16·8	16·3	12·7	12·0	2·2	232·0	44	+15	84	3	− 1	6·5	6·0	6·2	4489	6·0	1·07
August, . .	...	3·8	12·1	15·2	15·9	17·9	19·2	17·8	17·0	15·6	15·2	11·2	10·8	7·4	1·7	...	180·8	39	+ 9	76	1	− 4	8·0	7·1	7·6	2573	3·5	0·85
September,	...	...	0·2	4·9	10·8	14·1	13·9	14·7	16·4	13·1	11·0	9·4	9·0	3·8	...	...	121·3	32	+ 1	78	3	− 1	6·5	5·1	5·8	3778	5·2	1·32
October, . .	...	...	...	0·4	5·6	10·8	12·8	14·8	15·7	13·1	10·7	7·9	1·8	...	...	...	93·6	29	0	76	9	+ 2	6·4	6·3	6·4	2934	4·0	0·78
November,	...	...	...	...	...	1·8	3·9	9·0	8·9	6·7	4·0	0·8	...	...	...	...	35·1	14	−10	72	18	+ 9	8·4	8·3	8·4	2974	4·1	1·11
December,	...	...	...	...	...	1·7	4·5	6·2	6·6	4·8	0·9	...	...	...	...	...	24·7	12	− 7	53	16	+ 2	6·9	6·4	6·6	5952	7·2	1·22
Year, . . .	4·5	25·8	44·3	65·2	82·8	110·9	130·6	139·9	141·0	127·1	114·8	89·7	76·7	55·5	33·7	6·7	1249·1	28	+ 1	88	95	+17	7·6	6·6	7·1	48,537	5·5	1·00

Wind from Observations made at 9 A.M. *and* 9 P.M. *Number of Days it blew from certain directions.*

	N.	N.E.	E.	S.E.	S.	S.W.	W.	N.W.	Calm or Variable.
January,	2	2	10	1	2	3	9	1	1
February,	1	1	3	3	2	2	15	0	1
March,	3	0	3	3	4	4	11	2	1
April,	0	2	9	2	3	6	6	2	0
May,	2	1	9	1	1	3	9	3	2
June,	2	0	14	3	1	3	4	2	1
July,	1	4	6	0	1	1	16	0	2
August,	0	0	3	1	4	13	8	1	1
September,	1	2	3	1	0	2	14	4	3
October,	0	0	5	1	0	5	10	3	7
November,	2	1	6	5	2	2	12	0	0
December,	1	1	2	0	1	10	11	2	3
Year,	15	14	73	21	21	54	125	20	22
Per cent.,	4	4	20	6	6	15	34	5	6
Difference from Average 1764-1896,	0	−3	+2	+1	+1	0	−1	−2	+2

Number of Times the following Phenomena were observed.

	Gales.	Halos.	Thunder-storms.	Lightning.	Aurora.	Snow.	Hail.	Frost in Shade.	Frost on Grass.	Mist or Fog.	Dew.	Hoar Frost.
January,	0	2	0	0	0	5	5	17	23	2	2	6
February,	2	6	0	0	0	1	0	4	13	1	0	3
March,	3	7	0	0	0	5	1	4	12	0	0	2
April,	0	3	0	0	0	1	2	6	14	1	0	0
May,	1	0	0	0	0	0	2	0	6	3	0	0
June,	0	0	0	0	0	0	0	0	0	6	2	0
July,	1	5	2	0	0	0	0	0	0	1	4	0
August,	0	0	4	0	0	0	1	0	0	0	0	0
September,	2	5	1	0	0	0	0	0	0	0	5	0
October,	2	2	0	0	0	0	0	2	4	6	11	4
November,	1	3	0	0	0	2	1	2	5	3	0	1
December,	1	1	0	0	0	2	0	10	18	4	0	2
Year,	13	34	7	0	0	16	12	45	95	27	24	18
Difference from Average 1770-1896,	−16	?	+1	?	−4	−5	+2	?	?	+12	?	?

	Earth Thermometers. Read Daily at 9 A.M.							
	Mean Temperature.				Variability of Temperature.			
	3 ins.	12 ins.	22 ins.	Air Temp. at 9 A.M.	3 ins.	12 ins.	22 ins.	Air Temp.
January,	34°·8	37°·2	38°·0	34°·9	0°·8	0°·4	0°·3	3°·1
February,	37·1	37·2	37·1	41·0	1·8	0·6	0·4	3·9
March,	40·0	41·2	38·1	40·7	1·8	0·6	0·6	3·5
April,	42·2	43·2	42·5	44·0	1·3	0·4	0·3	2·8
May,	48·4	48·4	47·2	48·8	1·6	0·6	0·3	4·3
June,	55·0	53·8	52·0	54·9	2·2	1·0	0·5	5·3
July,	59·9	58·6	56·6	60·7	1·9	0·8	0·4	4·8
August,	60·5	60·5	58·9	60·8	1·3	0·5	0·3	2·2
September,	52·0	54·4	54·2	53·4	1·8	0·6	0·3	3·3
October,	47·1	49·6	49·7	47·9	2·1	0·6	0·4	4·3
November,	45·0	46·6	46·7	45·9	1·8	0·7	0·4	4·2
December,	37·4	40·0	40·9	39·7	2·4	0·8	0·4	4·3
Year,	46·6	47·6	46·8	47·7	1·7	0·6	0·4	3·8

II. *Nests, Eggs, and Play-grounds of the Australian* Ptilonorhynchinæ, *or Bower-Birds, and their Allies.* By Archibald J. Campbell, Esq., Melbourne. [Plates I.–III.]

(Read 15th December 1897.)

Ptilonorhynchus violaceus, Vieillot.

Satin Bower-Bird.

[Plate I.]

***Figure.*—Gould, Birds of Australia, fol., vol. iv. pl. 10.**
***Reference.*—Cat. B. Brit. Mus., vi. p. 381.**
***Descriptions of Eggs.*—Campbell, Southern Science Record (1883); Ramsay, P.L.S., N.S.W., 2nd Series, vol. i. (1886).**

***Geographical Distribution.*—Queensland, New South Wales, and Victoria.**

***Nest.*—Open, shallow; somewhat loosely constructed of twigs; lined inside with leaves (*Eucalyptus*), and placed in a scrubby bush or tree, at a height varying from about**

10 to 30 feet from the ground. Dimensions over all—diameter 7 or 8 inches by 5 inches in depth.

Eggs.—Clutch 2-3; shape well proportioned; shell moderately fine in texture; gloss just perceptible upon surface; colour varies from dark cream to dirty yellow, irregularly blotched and spotted with umber, reddish-brown, and a few purplish-grey markings. In some specimens the blotches are very bold, with the markings under the surface of the shell of a bluish-black shade. Occasionally there is a type with a lighter or paler coloured ground and smaller-sized markings. Dimensions in inches of a typical clutch:—(1) $1{\cdot}76 \times 1{\cdot}19$; (2) $1{\cdot}74 \times 1{\cdot}17$.

Except for their larger size, the eggs in colour and character much resemble those of the Oriole (*Mimeta viridis*).

Observations.—The Satin Bower-Bird—the male especially beautiful by reason of his lustrous blue-black coat and lovely violet eyes—is an inhabitant of the forests, more particularly of the coastal region, of Eastern Australia, from Northern Queensland down to the Cape Otway forest, Victoria.

At seasons Satin-Birds are very destructive in the gardens and orchards, eating clover, especially the flowers, English grass, cabbages down to the very root, and fruit. Mr W. B. Bailey, Pimpama Nurseries, South Queensland, informed me of an instance in which he had about three acres of mandarin oranges stripped in a week. The birds are also fond of sweet potato tubers. I noticed at Mr Bailey's residence a very handsome male bird which he had in captivity. It was in its youthful coat of mottled green when he first obtained it. It is interesting to learn that this bird did not don its full livery of blue-black till the fourth year. The bird was an excellent mimic, could talk, and imitate well the mewing of a cat.

It is somewhat remarkable that, notwithstanding the Satin-Birds are plentiful locally, the eggs are exceedingly rare in collections. On the 23rd November 1883 my young friend, Mr Lindsay Clark, found, near the Bass River, Western Port, a nest of the Satin-Bird containing a rare prize—a pair of fresh eggs. Mr Clark described the nest as being placed about 12 feet from the ground, in a scrubby bush, loosely

constructed of twigs, etc., and lined with leaves, and, on being removed from its position, it fell to pieces.

A most remarkable instance, and one fortunately for myself, happened the following season. Mr Clark went Mutton-Bird (*Puffinus brevicauda*) egging on Phillip Island, when it occurred to him to visit the mainland again in the neighbourhood of his Satin-Bird's nest of the previous season. The result was that he found another pair of eggs, which are now in my collection.

I never enjoyed the opportunity of taking a nest of the Satin-Bird, but at Christmas-tide 1884 I saw a perfect bower on the north shore of Lake King, Gippsland. The structure was situated in a cleared space upon the ground, amongst some bracken in open forest. The cleared space was 26 inches across, the bower or avenue being in the centre of this space. The two parallel walls of tapering twigs were about 12 inches high, by a breadth of 10 inches, and were 6 inches apart. The walls were somewhat curved, arching towards the top. The chief decorations within the bower, and round about, were the gay (red) feathers of the Crimson Lory (*Platycercus pennantii*).

The Satin-Bird's eggs which Dr Ramsay described in the *Proceedings of the Zoological Society* (1875) were of an abnormal type, if referable to that bird at all, hence his excuse for redescribing (and rightly so) two well authenticated sets collected by Mr Ralph Hargrave at Wattamola, New South Wales.

Dr A. E. Cox, Sydney, informed me that about the middle of October 1876, at Mittagong, New South Wales, he found a nest of the Satin-Bird situated on the top of a ti-tree (*Melaleuca*) stump, containing two eggs which were nearly incubated.

From Mr K. Broadbent's interesting articles on the "Cardwell Birds" I take, "the Black Satin Bower-Bird (*Ptilonorhynchus violaceus*) was observed at the Herbert River gorge, and quite commonly in the Herberton scrubs. In the latter locality it occurred in company with the Spotted Cat-Bird (*Ælurœdus maculosus*), and the Tooth-billed Bower-Bird (*Scenopœus dentirostris*), and Newton's

Bower-Bird (*Prionodura newtoniana*); in fact, I have seen all these four species feeding in the same tree. These Satin-Birds, as they are more popularly designated, may be often met with during the month of May in the open, along the edges of the scrubs, feeding upon the tops of young ferns.

BOWER OF SATIN BOWER-BIRD.

From a Photo by Mr D. Le Souëf. *From the "Australasian."*

I have seen flocks of two hundred or more, composed in large proportions of plain-coloured mottled birds, with about ten or twelve dark or deep blue-coloured individuals amongst them."

Regarding this Bower-Bird in Southern Queensland, I have in Mr Hermann Lan's MS. the following:—

"*Satin-Bird.*—The sea-coast scrubs are its haunts. Now and again it comes out to the open forest to feed upon the

berries of the mistletoe, or on the figs in gardens. Its agreeable note is a clear whistle from tenor down to bass. While the male bird is clad in a beautiful shining coat of dark blue, with eyes and base of bill to match, the female has only a simple (olive green) attire. The females, with probably immature males, have been seen in flocks far from their summer abode.

"Before nesting begins, the birds build up a play-ground (bower). The finest bowers are nearly in all cases on the sunny side of a lying log, the ground being strewn with moss, flowers, yellow and blue Lory parrot's feathers, small bones, and snail-houses, for about a yard in diameter. In the middle is erected a bower about 18 inches in height. When completed, several birds of both sexes run round and through the archway or avenue, picking up, in their joy, some of the nesting (? bower) materials and tossing them about, and we may guess, in their own way, choose partners.

"As I was watching one day at Cunningham Gap, a fine male bird with a withered fig-leaf in its bill, turning it over, became a prey to me. Half a mile away from the spot I found the nest (but no eggs), 10 feet from the ground, in a small scrub tree. The nest was made of dry sticks, and lined with dry leaves, and was rather shallow. Later, when residing in the Bunya Mountains, I had the satisfaction of getting again a nest with 2 eggs (usual complement), 10 feet from the ground—Date, January 1887."

I conclude with a brief account of a sensational nesting outing that Mr S. W. Jackson enjoyed amongst these fascinating birds. The notes, which Mr Jackson was kind enough to write specially for me, read as follows:—

"On December 23rd, 1896, I started from South Grafton and proceeded on my bicycle towards Cloud's Creek, some fifty-nine miles distant, in hopes of finding some good eggs in the scrubs in those parts. However, on reaching my destination, after a good day's riding on my machine, which was heavily loaded with tent, camera, rations, etc., I pitched my camp, and afterwards had a stroll among the 'oak' trees (two species of *Casuarina*). In answer to the cries or calls of the Satin Bower-Bird, I walked about fifty yards from

my camp, and was forced to stop at an oak tree, my notice being called to a female Bower-Bird which flushed out from a cluster of mistletoe in the tree. On climbing, I found a nest carefully concealed in the mistletoe, which contained 3 fresh eggs. The nest was constructed of similar material, etc., to that of the Black-throated Butcher-Bird (*Cracticus robustus*), only lined with leaves of the spotted *Eucalyptus* instead of small twigs.

"I carefully emptied the nest of its contents, but unfortunately the nest could not be removed, on account of the sticks of the same being so intermingled with the twigs of the mistletoe, the latter growing on a very thick limb. After making further searches, I succeeded in finding nine more nests, all of which were built in oak trees, and in same position as the first nest found, with the exception that four of them were built in the upright forks of the oaks, and not in the mistletoe as the remaining six were. In the nine nests found there were eggs in four of them, out of which I got one fresh set of 2, and a few addled eggs, the balance of the eggs being too far advanced in incubation to be blown. The remaining five nests *all* contained young birds covered with down, and in one nest I found one young bird possessing four legs, and I regret I did not keep the curiosity, instead of placing it back into the nest.

"In all, I only procured 7 eggs, which varied much in size and colour. Out of the ten nests found, the following is the detailed result:—

1	nest	contained	set of	3 eggs (fresh).
1	,,	,,	,,	2 eggs (almost fresh).
1	,,	,,	,,	1 egg (addled) and 1 bird.
4	nests	,,	,,	3 young birds each.
2	,,	,,	,,	2 eggs each (heavily incubated).
1	nest	,,	,,	3 eggs (1 addled, 2 heavily incubated).

"The majority of the nests were 100 or 200 yards apart, at an elevation of about 20 to 30 feet, and mostly placed near the trunk of the tree, just where the smaller twigs branch off near the topmost part. The birds were very tame, and allowed their nests to be robbed without attempting to attack the intruder.

"I spent four days by myself in this wild bush, away from all civilisation, and tried my best to find more nests of the Bower-Bird, but only succeeded in finding two old nests (perhaps last season's).

"While I was busily climbing up to one of the Satin-Bird's nests, and when nearing same, I got rather an unexpected shock at finding an iguana (a reptile about 3 or 4 feet long) eating, or starting to eat, one of the heavily incubated eggs. The ugly creature, in its sudden amazement, jumped on my head, and then descended to the ground. The feeling to me was very unpleasant, and of rather a rare nature."

The breeding months extend from October to January.

ÆLURŒDUS VIRIDIS, Latham.

Cat-Bird.

Figure.—Gould, Birds of Australia, fol., vol. iv. pl. 11.
Reference.—Cat. B. Brit. Mus., vi. p. 384.
Descriptions of Eggs.—North, Records Austn. Mus., vol. i. (1891).

Geographical Distribution.—South Queensland and New South Wales.

Nest.—Open, somewhat deep, with thick sides; outwardly composed of twigs and broad leaves holding the decomposed earthy matter of the Nest-fern (*Asplenium nidus*); lined inside with fine twigs and rootlets; usually situated near the top of a sapling or small tapering tree, at a height of from 4 to 20 feet, sheltered by the densest scrub. Dimensions over all 9 or 10 inches, by 6 or 7 inches in depth; egg cavity, 5 inches across by 3 inches deep.

Eggs.—Clutch 2-3; shape inclined to oval, more pointed towards one end; texture of shell somewhat fine; surface glossy, and of a uniform rich or dark creamy colour.

Dimensions in inches:—Full clutch (1) $1·76 \times 1·24$; (2) $1·75 \times 1·23$; (3) $1·72 \times 1·23$. Of a pair—(1) $1·69 \times 1·2$; (2) $1·68 \times 1·18$.

Observations.—This most extraordinary bird is a denizen of the thick jungle-like scrub which clothes portions of the

coastal regions of New South Wales and Southern Queensland.

During my visit (1891) to the "Big Scrub" of the Richmond River district, the peculiar voice of this bird was heard everywhere throughout the locality. The cry is a real cat-like "mew-mew," with a strong accent on the second "mew," as if some one had trodden on a cat's tail. I happened to observe a pair of birds "caterwauling" about a nest, which was situated about 15 feet from the ground, in a small tree on the bank of Pearce's Creek. I climbed to the nest, only to be disappointed in finding a pair of young, clothed in down as black as ink, instead of a set of the rare, cream-coloured eggs.

My companion, Mr W. T. Bailey, and I found several other nests of the Cat-Bird in the course of construction, or ready for eggs, but we had to turn our backs on the "Big Scrub" without securing such coveted eggs. The nest, of which the description is given above, was felled by scrub-fellers, the contents of course being smashed. However, a pair of eggs, taken by Mr James Gordon, soon followed me home. The nest was found in a young Buryong tree (*Tarrietia*), at a height of 15 or 16 feet from the ground—Date, November 1891. Subsequently, Mr Bailey kindly sent me from the same district a lustrous set of 3 eggs, taken on the 23rd December 1894.

The first authenticated finds of Cat-Bird's eggs were by Mr Henry R. Elvery, Richmond River (1881), and by my venerable friend Mr Hermann Lan, South Queensland (1886). These finds were not reported at the time, and the credit fell to Mr W. J. Grime for a nest and egg which he procured in the Tweed River district, and forwarded to the Australian Museum. The following is Mr Grime's account, as given in the *Records* of that institution:—"On the 4th October 1890 I was out looking for nests, accompanied by a boy. I left him for a little while to go farther in the scrub, and on my return he informed me he had found a Cat-Bird's nest with 2 eggs, one of which he showed me, the other one he broke descending the tree. I went with him to the nest, and found the old birds very savage, flying at us, and fluttering along

the ground. The nest was built in a three-pronged fork of a tree, about 14 feet from the ground. The tree was only 4 inches in diameter, and was in a jungle of light scrub, about 50 yards from the edge of open country. I felled the tree and secured the nest."

A beautiful figure of the nest is given in the *Records.*

From Mr Lan's manuscript notes I take—

"The name Cat-Bird is derived from its lamentable noise, not unlike that of a cat, but more that of a crying child. In the dense scrub at Cooyar, a little south of the Bunya Mountains, the oft repeated sound was aggravating to me, so, when I could get a glimpse of the bird, a gunshot made an end to my ghastly neighbour. It was November 1886, at Cunningham's Gap, where I happily found a nest 5 feet from the ground, between the triple fork of a young tree, and an exquisite nest it was. Half way up from the bottom consisted of dry fig-leaves, beautifully fastened with twining rootlets, and stronger ones from the rim, and lined with dry grass and roots. Finding only 1 egg in it, I waited for two days more, when there were 2. I concluded such to be the clutch. Although it is said that the Cat-Bird makes a bower, I never saw one of its own, but several times have seen it poking about the bower of the Satin-Bird."

Breeding months include from about the middle of September to January.

ÆLURŒDUS MACULOSUS, Ramsay.

Spotted Cat-Bird.

Figure.—Gould-Sharpe, Birds of New Guinea, vol. i. pl. 38.

Reference.—Cat. B. Brit. Mus., vi. p. 385.

Descriptions of Eggs.—North, P.L.S., N.W.S., vol. iii., 2nd Series (1888); Le Souëf, Proc. Roy. Soc. Victoria, vol. vii., New Series, p. 20 (1894).

Geographical Distribution.—North Queensland.

Nest.—Open, bulky; outwardly composed of leaves and twigs, mixed with fine rootlets; lined inside with fine wire-like tendrils; usually situated near the top of a slender tree

in dense scrub. Dimensions over all about 9 inches, by 4½ inches in depth; egg cavity, 5¾ inches across by 2 inches deep.

Eggs.—Clutch 2-3, usually 2; shape inclined to oval, more pointed towards one end; texture of shell somewhat fine; surface glossy, and of a uniform cream colour.

Dimensions in inches of a full clutch:—(1) a somewhat lengthened example, $1{\cdot}7 \times 1{\cdot}06$; (2) $1{\cdot}58 \times 1{\cdot}14$; (3) $1{\cdot}47 \times 1{\cdot}13$. Of a clutch of 2:—(1) $1{\cdot}58 \times 1{\cdot}03$; (2) $1{\cdot}5 \times 1{\cdot}1$.

These eggs may be readily distinguished from those of the southern Cat-Bird by their smaller size and lighter colouring.

Observations.—To Australia belong two species of this peculiar genus, the one under notice being the northern and smaller representative of the Cat-Bird of New South Wales. The Herbert River, Mr Broadbent remarks, would appear to be the southern limit of the Spotted Cat-Bird.

My friend, Mr Dudley Le Souëf, who has also explored the palm scrubs of Northern Queensland—the domains of the Spotted Cat-Bird—and to whom I am indebted for a pair of eggs, taken 27th October 1893, says:—"The curious harsh note (not resembling the cat-like cry of the southern bird) of the Spotted Cat-Bird was often heard in the scrub, and several nests found. They appear to prefer building near the top of a slender tree, about 15 feet from the ground, although on one occasion we found one within 2 feet, built on a creeper, but that was an exception."

The birds do not appear to be at all shy. Mr Le Souëf saw one speared by a native in thick scrub.

Mr North states that during an excursion to the Bellenden-Ker ranges, Messrs E. J. Cairn and Robert Grant, collecting on behalf of the trustees of the Australian Museum, succeeded in obtaining, among others, a fine series of Spotted Cat-Birds in different stages of plumage, and, besides finding several nests with young birds, they were fortunate in obtaining a nest with 2 eggs. The nest and eggs were found in the fork of a small sapling, about 7 feet from the ground,

on the Herberton road, at a distance of thirty-two miles from Cairns. Both parent birds were secured at the time of taking the eggs, which were in an advanced state of incubation.

Breeding months, September to December or January.

Although these two species of Cat-Birds are included in the Bower-Bird family, so far as observations have gone, they do not build bowers, nor have any particular playing-places been noticed by observers. Perhaps they possess some insignificant playing-place—merely a bare spot of earth, with a few leaves placed thereon, like the play-ground of the Tooth-billed Cat-Bird (*Scenopœus*)—or perchance the birds select a stump or log, which they frequent to play, like the Rifle-Bird (*Ptilorhis*).

CHLAMYDODERA MACULATA, Gould.

Spotted Bower-Bird.

[Plate II.]

Figure.—Gould, Birds of Australia, fol., vol. iv. pl. 8.

Reference.—Cat. B. Brit. Mus., vi. p. 389.

Descriptions of Eggs.—Ramsay, P.Z.S., p. 605 (1874); Ramsay, P.L.S., N.S.W., vol. vii. (1882); Campbell, Southern Science Record (1883); North, P.L.S., N.W.S., vol. i., 2nd Series (1886).

Geographical Distribution.—Queensland, New South Wales, Victoria, and South Australia.

Nest.—Flat, somewhat concave; loosely constructed of dead twigs or fine sticks; lined inside with finer twigs and grass; usually situated in a thick bush or tree in open forest country. Sometimes the nest is so frail that the contents may be seen through the structure from underneath. Dimensions over all, 10 inches in diameter.

Eggs.—Clutch 2, occasionally 3; shape inclined to oval, more pointed towards one end; texture of shell fine; surface slightly glossy; ground colour light greenish-yellow. There

are three distinct characters of markings, firstly, light greyish blotches appearing on the inner surface of the shell; secondly, small stripes or hair-like lines of light sienna and umber, painted, as if with a camel-hair brush, in every shape and size round the shell, principally zig-zagged latitudinally, but often taking longitudinal and other directions; and, lastly, over these a few darker and heavier stripes and smudges of umber. Both ends of the egg are comparatively free from markings. Dimensions in inches of odd examples:—(1) $1{\cdot}65 \times 1{\cdot}08$; (2) $1{\cdot}64 \times 1{\cdot}06$. A clutch with more of a yellowish-white ground, and with both ends much freer from markings, measures (1) $1{\cdot}57 \times 1{\cdot}06$; (2) $1{\cdot}5 \times 1{\cdot}07$.

The eggs are very beautiful and most singular in appearance, resembling fine porcelain with hand-painted markings.

Observations.—The beautiful Spotted Bower-Bird is a dweller of the dry interior provinces.

In a Riverina timber-belt, with its venerable and dark cone-shaped pines (*Callistris*), with every branch and branchlet, dead and living, bedecked with ornamental lichens; their sombre character is relieved by the interspacing silvery, needle-like foliage of Hakea trees of lower growth, bearing a crop of curiously-fashioned seed-balls; a species of Acacia with short stiff leaves, and with wood not unlike the West Australian jam-wood for aroma, by its floral stores is celebrating "yellow-haired September"; the Quondong tree (*Santalum*), whose pendulous foliage clings like skirts about its dark rough stem, is also seen, besides other dwarf trees called by lengthy botanical names; while all around the rich, red ground, well grassed, sparkles with the flowers of small white immortelles,—such is the home of the Spotted Bower-Bird as I saw it once in spring.

There has been some discussion as to who first found the genuine eggs of the Spotted Bower-Bird. I believe (and it is only my belief, without any direct proof, and therefore I am open to correction) that some of the earlier recorded finds, especially those on the coast of the northern portion of New South Wales, were none other than the eggs of the

Regent-Bird (*Sericulus melinus*). These coastal scrubs are the stronghold of the Regent-Bird, whereas the Spotted Bower-Bird, as I have stated, seeks generally the dry and arid parts of the interior. I have also the testimony of a keen observer in the former locality that the Spotted Bower-Bird is scarce there. Moreover, nothing would be easier, at first sight, than to mistake a female Regent-Bird for a Spotted Bower-Bird when flushed from its nest.

The first authenticated egg discovered of the Spotted Bower-Bird was probably that found by Mr J. B. White, and described by Dr Ramsay, *vide Proceedings of the Zoological Society*, 1874. The same year (1874) Mr Hermann Lan discovered a nest of this Bower-Bird near Whitstone, South Queensland. I shall quote from his MS. his original and interesting note.

"This bird makes for the fruit when it ripens in the garden, especially the figs. The scrub, where it comes from, grows on a sandy bottom in the neighbourhood of the station. In this scrub I several times espied the bower of the bird, not like the edifice of the Satin-Bird, which is closed on the top, but open. A cartful of bones—the vertebræ of sheep predominating—pieces of glass, unripe wild fruit, even a shilling, sometimes betray the entrance of the bower.

"While bathing one afternoon in M'Intyre Creek, half a mile from the scrub, I observed a Bower-Bird flying with a caterpillar in its bill. After dressing, I followed in the direction, and found its nest high in a ti-tree (*Melaleuca*) over the water, and, procuring a ladder, beheld two young in the nest. Eventually, I took the nest and young home, feeding the young for two months, as long as the season lasted, but at last they died.

"At the same place (Whitstone) I again got a nest with 2 eggs, December 1874. The nest represents small sticks, like that of a pigeon, but lined with grass, etc."

When Mr Lan was returning to his fatherland, this particular nest and eggs found a secure resting-place in the beautiful collection of Mr D. Le Souëf at the Royal Park, Melbourne.

In 1875 Mr James Ramsay, according to Mr A. J. North, obtained several specimens of eggs, with the birds, at Tyndarie (New South Wales).

About the end of October 1877, while searching for specimens along a billabong of the river Darling, not far from Wentworth, New South Wales, I found a nest, about 20 feet from the ground, near the top of a red-green (*Eucalyptus*) sapling in a belt of timber. A bird (probably the hen) was sitting, and did not leave until I had climbed close to it. The nest was loosely composed of sticks and twigs, and lined inside with finer twigs and grass, and contained 1 fresh egg, the most remarkable for beauty, and the wonderful character of its markings, that it has ever been my fortune to find.

A nest of a Spotted Bower-Bird was pointed out to me, from which a pair of beautiful eggs was taken on the 14th November 1894. The nest was the usual frail structure, built at the height of about 30 feet from the ground, near the top of a pine tree (*Callistris*). The tree was situated about 200 yards from a dwelling on Neimur Creek, Riverina, and was discovered by one of the lads tracking the bird while carrying a twig to construct its nest. The eggs, which are of a light coloured type, are now in the collection of Mr Joseph Gabriel, Abbotsford, Victoria.

It appears the Spotted Bower-Bird occasionally lays 3 eggs. Mr R. Macfarlane, formerly of the Maller Cliffs station, New South Wales, found a nest containing 3 eggs in a needle-bush (*Hakea*). While the specimens awaited a favourable opportunity to be sent to Melbourne for my collection, the station cook, it is supposed, took a fancy to them, for they somehow mysteriously disappeared. Again, Mr W. L. Hutton, writing to me from Lessington, near Bourke, says:—"I saw three nests of the Bower-Bird last season (1895), one of which had 3 eggs in it."

The note of the Spotted Bower-Bird is somewhat harsh and scolding. But it is not generally known, nor has it been properly recorded, that these birds are accomplished mocking creatures, as several of my bush friends can attest. The Misses Macaulay, of "Bannockburn," Riverina, had one

or two birds which, at certain seasons, regularly, between 10 o'clock in the morning and 2 in the afternoon, used to visit the pepper trees in the garden, where the birds were heard imitating the calls of the noisy Miner (*Myzantha*); Magpie (*Gymnorhina*); the Crow, but not quite so hoarsely; and Chatterers (*Pomatostomus*); while the screech of the Whistling Eagle was so realistic as to cause a domestic hen and chickens to fly for cover, although no bird of prey was nigh. The Bower-Bird also reproduces well the sound of a maul striking the splitter's wedge, and other familiar sounds, such as the mewing of cats, barking of dogs, etc.

Mr G. H. Morton, of Benjeroop, relates an amusing experience regarding the mimicry of the Spotted Bower-Bird. His neighbour had been driving cattle to a given place, and on his way back discovered a nest in a prickly needle-bush or Hakea tree. In "threading" the needle branches after the nest, he thought he heard cattle breaking through the scrub, and the barking of dogs in the distance, and at once fancied his cattle had broken away, but could see no signs of anything wrong. He heard other peculiar noises, and glancing at his dog, as much as to say, "What does it mean?" he saw the sagacious animal, with head partly upturned, eyeing a Bower-Bird perched in the next tree.

Although Gould has cleverly described the bower of this species, and, moreover, succeeded in taking one to England, which is now in the British Museum, and other authors have mentioned these wonderful structures, without unnecessarily extending the present observations, I may state that during our memorable "flood" trip through Riverina, September 1893, Mr J. Gabriel and I embraced the opportunity of examining on the Pine Ridges six of the avenues or playing-grounds—all apparently in use—of the Spotted Bower-Bird. Some of these singular structures we successfully photographed. They were under bushes, usually the Prickly Bursaria, and consisted of a pair of parallel walls of sticks, grass, etc., stuck into the ground and erected on end, and heaped about with bones, chiefly placed about either entrance.

I give details of three of these bowers, which may be taken as types.

BOWER OF SPOTTED BOWER-BIRD.

From a Photo by the Author. *From the "Australasian."*

1. Under a clump of Bursaria bushes, with thistles and other vegetation growing near—platform or approach larger at one entrance. Space immediately around the bower and centre of avenue-like walk composed of dead twigs, well trampled down. Exterior portion of walls composed of twigs; interior side of walls composed of yellowish grass stalks, with the seeding parts uppermost. Number of bones —leg-bones, ribs, and vertebræ of sheep—90 at one entrance, 92 at the opposite. Inside the bower were 24 bones. Other decorations inside and round about were—pieces of glass, 24; Hakea seeds, 30; Quondong (*Santalum*) seeds, 4; and green pine branchlets, 2.

2. At the edge of the Mallee (species of *Eucalyptus*) scrub, under Bursaria bushes, with pines and Bull-oaks (*Casuarina*) near. Bones placed just at entrances; bower somewhat open, and concaved towards the centre of the floor; built principally of a species of coarse tussocky grass and *Casuarina* needles or foliage.

3. Situated under native "Hop" bush, and slightly curved in shape; principally constructed of coarse tussocky grass and Casuarina needles, with a few branching twigs placed outermost. Usual heap of bones at either entrance, also bits of glass, Quondong, Hakea, and other seeds, portions of Pig-face weed (*Mesembryanthemum*), pieces of Emu egg-shell, etc. In centre a handful of bones (15) and Quondong seeds (8).

Statement showing the dimensions in inches of three ordinary sized play-grounds or bowers of the Spotted Bower-Bird:—

	Total Length of Play-ground.	Length of Bower.	Breadth of Bower from Outside Walls.	Width Inside.	Height of Walls.	Thickness of Walls.
1	62	17	20	6–7	15	5–6
2	42	18	16–17	7–8	12	4–5
3	63	27	27	6–9	10–12	8–9

Lost jewellery, coin of the realm, etc., have often been recovered at bowers. It is said that any decorations of the bower by human hands is resented by the birds, the items, however beautiful, being thrown out. However, if the bones, etc., belonging to the bower be scattered, the birds will always gather them together again.

It has also been stated, but I have not been able to verify it, that this Bower-Bird discriminates colours, and that it will carry nothing of a bright red nature to its play-ground.

With reference to Gould's *C. occipitalis*, Dr Ramsay, who has examined the type, pronounces it to be only a fine-plumaged adult male of *C. maculata*.

CHLAMYDODERA GUTTATA, Gould.

Yellow-Spotted or Guttated Bower-Bird.

Figure.—Gould, Birds of Australia, fol., Sup., pl. 35.
Reference.—Cat. B. Brit. Mus., vi. p. 390.

Geographical Distribution.—North-West Australia, Northern Territory, and Central Australia.

Nest and Eggs.—Unknown.

Observations.—Gould was indebted to Mr T. F. Gregory, the West Australian explorer, for the first specimen of this little-known species in North-West Australia.

The bird is spotted, like the *C. maculata*, but differs in the guttations of the upper surface, being larger in size and more distinct, the abdomen being buff, and the shafts of the primaries a richer yellow. Subsequently Sturt, on his trans-continental journey, met with the bird, and lately (1894) the Guttated Bower-Bird was again reported in Central Australia by the Horne Scientific Expedition.

A valued correspondent, Mr Tom Carter, found a Bower-Bird near the North-West Cape, which, I believe, is referable to this species.

In reference to this bird's supposed playing-bower, Gould quotes from Sir George Gray's "Travels," in which that author writes:—"This very curious sort of 'nest,' which was frequently found by myself and other individuals of the party, not only along the sea-shore, but in some instances at a distance of six or seven miles from it, I once conceived must belong to a kangaroo, until I was informed that it was a run or playing-place of a species of *Chlamydodera.* These structures were formed of dead grass and parts of bushes, sunk a slight depth into two parallel furrows in sandy soil, and then nicely arched above. But the most remarkable fact connected with them was that they were always full of broken sea-shells, large heaps of which protruded from each extremity. In one instance, in a bower the most remote from the sea that we discovered, one of the men of the party found and brought to me the stone of some fruit which had evidently been rolled in the sea; these stones he found lying in a heap in the nest, and they are now in my possession."

CHLAMYDODERA NUCHALIS, Jardine and Selby.

Great Bower-Bird.

[Plate III.]

Figure.—Gould, Birds of Australia, fol., vol. iv. pl. 9.
Reference.—Cat. B. Brit. Mus., vi. p. 391.

Geographical Distribution.—Northern Territory, West and North-West Australia.

Nest and Eggs.—Unknown.

Observations.—This exceedingly fine species is the western ally of the Queensland Bower-Bird (*C. orientalis*), and the largest of its genus. Little is known of this species.

Captain Stokes, in his "Discoveries of Australia," mentions the remarkable bowers of this bird which he had seen at the Victoria River. To Mr H. H. Johnston of the Survey Office, Western Australia, I am obliged for photographs he took of a fine bower at Cambridge Gulf. The structure was about 30 inches through the avenue, which was about 18 inches wide at either end, and with walls about the same dimensions in height. The bower was built of fine twigs, and heaped about, principally at the entrances, with bleached shells. The centre of the avenue also contained a few shells and stones.

CHLAMYDODERA ORIENTALIS, Gould.

Queensland Bower-Bird.

Figure.—Gould-Sharpe, Birds of New Guinea, vol. i. pl. 44.
Reference.—Cat. B. Brit. Mus., vi. p. 392.
Description of Eggs.—North, Victorian Naturalist (1896).

Geographical Distribution.—North Queensland and Northern Territory (probably).

Nest.—Flat, slightly concave; loosely constructed of coarse twigs, and lined with finer twigs; usually placed in a small tree or sapling in scrub. Dimensions over all—diameter, 8 to 10 inches, by 4 inches in depth. Usually placed at a height of about 10 to 12 feet from the ground, in open forest country.

Eggs.—Clutch, 2; shape, roundish oval, slightly pointed towards one end; texture of shell fine; surface glossy; colour light greenish-grey, curiously but moderately streaked with

wavy line-like markings of amber and light slate. The majority of the markings take a latitudinal direction, crossing and recrossing each other, while some of the heavier lines take longitudinal or various directions. There are also a few fancifully-shaped dark blotches here and there over the shell.

Dimensions in inches of odd examples:—(1) 1·68 × 1·12; (2) 1·57 × 1·16. Of a clutch much marked all over, including both ends, with extraordinary hair-like lines:—(1) 1·52 × 1·12; (2) 1·54 × 1·1.

Observations.—This very fine species inhabits Northern Queensland, probably extending its range into the Northern Territory. It would, indeed, be interesting to learn, as Mr North remarks, where the eastern and north-western races—*C. orientalis* and *C. nuchalis*—meet.

Mr Kendall Broadbent obtained the Queensland Bower-Bird during September at Herbert Vale. He also met with it at the Herbert Gorge, and although he found this bird at Bowen and near Townsville, it is in the Gulf of Carpentaria district that seemed to Mr Broadbent to be the bird's true home, and nowhere did he meet it more plentiful than at the mouth of the Norman River. It was at this river that Mr Broadbent collected the interesting group of birds and bower which may be seen in the National Museum, Melbourne.

The following original notes I have received from Mr Ed. Cornwall, Burdekin River district, relative to this Bower-Bird:—"I think I have discovered a new trait in the character of the Queensland Bower-Bird. They are very plentiful about Roseneath Garden, and are very destructive to the crops; chillies, paw-paws, granadillas, guavas, mangoes, peas—in fact, every description of fruit suffers to a greater or less extent from their depredations. But their last object of attack proves them to be not entirely vegetarians, unless new-laid eggs be called diet for non-eaters of flesh! This is not mere supposition, but hard fact, for after noticing the disappearance of eggs in a most unaccountable manner for some time, the gardener kept watch, and was rewarded by seeing Mr Bower-Bird fly straight to a nest vacated by a fowl, and deliberately devour its contents. This may not be a remarkable incident, but to me it certainly appeared strange."

Again writing, Mr Cornwall says:—"*Re* the Queensland Bower-Bird, since writing you last I have had further evidence to convict this rogue of what I charged him with. A bird was seen to fly right to the fowl's nest in an empty shed, and immediately afterwards emerge with an egg in its long claws. But it proved rather a heavy burden, for the bird dropped it ere he had gone many yards."

Again the same correspondent favours me:—"I very often come across their playing-bowers. Two years ago they built a very fine one on the roof of the verandah of this house. I was not living here then, but have often seen the birds playing about it, and amongst the branches of two large Poinciana trees which droop right over the roof."

During a recent tour to Northern Queensland, Mr Dudley Le Souëf took a very successful photograph of a play-house of this Bower-Bird.

BOWER OF THE QUEENSLAND BOWER-BIRD.
From a Photo by Mr D. Le Souef.

As might be expected, the eggs of the Queensland Bower-Bird possess the remarkable characteristics of those of the

Spotted Bower-Bird. During the season 1895, Mr Charles French (through his worthy father Mr Charles French, F.L.S.) experienced a windfall which gave collectors a pleasant surprise, two pairs of handsome eggs, collected during August in the vicinity of the Gregory River, reaching Mr French's collection. With thoughtful kindness, Mr French at once divided the second pair between his old friend Mr G. A. Keartland and myself.

Mr A. J. North, of the Australian Museum, Sydney, happened shortly afterwards to visit Melbourne. He was also surprised to see that the fine eggs had been "over carried"—that is, past Sydney. But he was not to be outdone in the matter of the first description. He had (and I commend him for his astuteness) three out of the four eggs described, and two of them figured in the *Victorian Naturalist*, almost before the owners were cognisant of the fact.

In the season of 1896, Mr E. Cornwall found a nest containing two eggs of the Queensland Bower-Bird. The nest, which was placed in a small river "oak" (? *Casuarina*) in a little scrub composed of the same trees, on the bank of Canal Creek, a tributary of the Alice River, very much resembled that of the Butcher Bird (*Cracticus*), but was much less strongly built; in fact, so loosely was it put together that Mr Cornwall says it fell to pieces when he endeavoured to remove it.

In November, the same season, my friend Mr D. Le Souëf found a nest of this fine Bower-Bird in open forest in the Bloomfield River district. The nest was at the height of 12 feet from the ground, near the end of a horizontal *Eucalyptus* branch, and contained one egg. Near the same locality he had the opportunity of examining and photographing a bower which was situated under a low, thick bush. The avenue was about 2 feet in length, and 5 inches wide; the parallel walls, which nearly touched each other at the top, were about 14 inches high by about 5 inches through their thickest part. There was a fair heap of bleached bones at either entrance.

CHLAMYDODERA CERVINIVENTRIS, Gould.

Fawn-breasted Bower-Bird.

Figure.—Gould, Birds of Australia, fol., Sup., pl. 36.
Reference.—Cat. B. Brit. Mus., vi. p. 393.
Description of Eggs.—North, P.L.S., N.S.W., 2nd Series, vol. i. (1886).

Geographical Distribution.—North Queensland, also New Guinea.

Nest.—Open, cup-shaped; composed of twigs, pieces of bark and moss, and lined with grass, etc.; usually built near the ground (North).

Eggs.—Clutch most probably 2. Very like that of *C. maculata* in colour, with the same peculiar linear markings crossing and recrossing each other all around; but confined more to the larger end of the egg than is usually the case in *C. maculata.* A specimen of this egg in the Australian Museum collection, taken at Cape York, measures 1·4 inch in length by 1·03 inch in breadth (North).

Observations.—As recorded by Gould, the discovery of this species is due to Mr Macgillivray, who procured a specimen at Cape York, which, with its curious bower, was transmitted to the British Museum.

The Fawn-breasted Bower-Bird is also found on the adjacent coast of New Guinea, as well as on some of the intermediate islands in Torres Straits, and may be recognised by the absence of the rose-pink frill on the back of the neck, as worn by the males of the other members of this interesting genus. Mr Macgillivray hinted that this bird was a mocking-bird.

The bower above mentioned has its walls, which are very thick, nearly upright, or but little inclining to each other at the top, so that the passage through is very narrow. It is formed of fine twigs, is placed on a very thick platform of thicker twigs, and is nearly 4 feet in length by about the same in breadth, and 18 inches high. Mr Macgillivray found the bower situated near the border of a scrub, which was not more than 10 feet high, growing on smooth sandy soil with-

out grass. There were some fresh berries and small land shells lying about the bower.

SCENOPÆUS DENTIROSTRIS, Ramsay.

Tooth-billed Cat-Bird.

Figure.—Gould-Sharpe, Birds of New Guinea, vol. i. pl. 43.
Reference.—Cat. B. Brit. Mus., vi. p. 394.

Geographical Distribution.—North Queensland.

Nest and Eggs.—Unknown.

Observations.—So far as is known the Tooth-billed Bower-Bird is restricted to the scrubs of Northern Queensland. Mr Kendall Broadbent writes:—"This interesting species has been obtained by me on the Tully River, 24 miles from Cardwell, at Cairns, at Herbert Gorge, and at Sea View Range, as far above the level of the sea as the scrubs extend, but always in the mountains, stray individuals only descending below 2000 feet.

"It excels all other Bower-Birds as a mimic, and may be fitly termed the master mocking-bird of Australia. Not only will it imitate the note of every bird in its neighbourhood, but so closely does it do so, that they are drawn to it as to one of their own kind. This is especially the case during the breeding season, and in May I have remained at one spot in the Herberton scrubs by the half hour, listening with wonder to its changeful utterances. Its bower, or dancing-ground, is of a unique description; a small portion of the ground of the scrub being rendered perfectly bare for the space of a square yard or so, save the presence of seven to nine large leaves, which the bird has placed therein, and with which it plays. These leaves, which are those of a particular kind of tree, it renews every morning."

Mr Broadbent has kindly given me an original sketch showing the locality and one of these circular play-grounds found by him in the Cardwell ranges.

Mr Le Souëf tells me that during his peregrinations in the Bloomfield River district he came across about a dozen play-grounds of the Tooth-billed Cat-Bird. They were found in

the dense scrub of the high country. He was usually attracted to the particular spot by the birds whistling near.

Upon the cleared play-ground is placed about nine oval-shaped moderately-sized (about 3 inches long) leaves, a few inches apart. Mr Le Souëf agrees with Mr Broadbent that the leaves are from one kind of tree, with the additional information that the leaves are always placed face downwards—perhaps the soft, lighter-coloured appearance of the underside of the leaf is more pleasing to the birds.

Mr Le Souëf took a photograph of one of these play-grounds, but the difficulties of the dense shade mitigate against its complete success.

Oologists are on the tip-toe of expectation for the discovery of the nest and eggs of this interesting scrub-dweller, also for further information respecting the nidification of its cousin of more "architectonic wisdom"—the richly-coloured Golden Bower-Bird (*Prionodura newtoniana*).

SERICULUS MELINUS, Swainson.

Regent-Bird.

Figure.—Gould, Birds of Australia, fol., vol. iv. pl. 12.
Reference.—Cat. B. Brit. Mus., vi. p. 395.
Descriptions of Eggs.—Ramsay, P.L.S., N.S.W., 2nd Series, vol. i. (1886); Campbell, Proc. Roy. Soc. Victoria (1892).

Geographical Distribution.—South Queensland and New South Wales.

Nest.—Flat, slightly concave; loosely constructed of coarse twigs or dead branchlets, lined on top with fine brownish twigs and long yellowish wire-like stems of a climbing plant, the latter being chiefly placed round the side; usually situated in dense scrub at the height of from 12 to 25 feet from the ground. Dimensions over all, 12 inches long by 6 inches broad, and by 2 inches thick.

Eggs.—Clutch 2; sometimes 3. In a clutch of 2—(1) is a beautiful, well-shaped specimen, with texture of shell fine and surface slightly glossy; colour, light yellowish-stone

with a faint greenish tinge, marked with blotches and spots of sienna, but chiefly with remarkable hair-like markings of the same colour as if a person had painted on the shell fanciful shapes and figures with a fine brush. Intermingled are a few dull, greyish streaks. All the markings are fairly distributed, being more abundant around the upper quarter; (2) is similar to the other specimen, but markings less pronounced and finer in character, with a greater proportion of the dull, greyish, hair-like streaks. Dimensions in inches:—(1) $1{\cdot}57 \times 1{\cdot}1$; (2) $1{\cdot}55 \times 1{\cdot}07$.

A second clutch is similar to the above, but has markings like a net-work all over, and finer or more hair-like in character. Dimensions:—(1) $1{\cdot}58 \times 1{\cdot}06$; (2) $1{\cdot}52 \times 1{\cdot}04$.

The eggs of the Regent-Bird resemble, in a remarkable degree, those of the Spotted Bower-Bird (*Chlamydodera maculata*), with the slight difference that the ground-colour of the eggs of the former is usually more yellowish in tone.

Observations.—The Regent-Bird has a somewhat restricted range, being chiefly confined to the sub-tropical coastal scrubs of the northern portion of New South Wales and Southern Queensland; but its extreme southern limit appears to be Port Jackson in the south, where the bird has been occasionally observed, and the Fitzroy River in the north. With regard to the latter locality, Mr George Potts, jun., Rockhampton, wrote: "a few Regent-Birds have made their appearance during this month (December 1885) and the latter end of last." I have also recorded having received a skin of a young male from Duaringa, near that river.

The Regent-Bird, especially the adult male with glorious black and golden-orange plumage, Gould has well said is one of the finest of Australian birds. The youthful male resembles the female; the second year the bill is yellowish; the third year the plumage is complete.

In November 1891, I undertook an excursion to the Richmond River district, New South Wales, with a view of obtaining, amongst other items, the eggs of the Regent-Bird. I was all the more anxious to obtain them, because the description of the only egg of this species known was

from an example taken from the oviduct of a bird shot by Mr James Cockerell, the collector, many years ago.

I found the luxuriant scrubs abounding with Regent-Birds, in fact they were as plentiful there as the Wattle-Birds (*Acanthochæra*) about the Banksia groves of our southern coast. I experienced no difficulty in procuring a few specimen skins, and all that was necessary was to select a balmy day and recline under a Canthium tree, where the birds (males, in various stages of plumage, and females) come to regale themselves on the bunches of hard yellow berries. But although well aided by a hardy companion—Mr W. T. Bailey—I prosecuted a vigorous and toilsome search through dense labyrinths of humid scrub and thorny brakes of prodigal growth, while the thick foliage of the taller trees caused a perpetual twilight underneath, yet I returned without the eggs. It was an experience akin to seeking for the proverbial needle in a haystack.

From evidence gained by dissection and otherwise, it appeared that November was too early for the majority of these birds. Just prior to quitting the district (19th November) we detected a female Regent-Bird carrying a twig, and after much laborious work we succeeded in tracking her through an entanglement of wild raspberries and stinging trees, and were satisfied that she was building in a certain bushy Buoyong (*Tarrietia*) tree, after seeing her return several times, each time with a twig in her bill. Marking the tree, we pointed it out to two young farmers, directing them to send the eggs after us. Some weeks subsequently I received a doleful letter stating they were unable to climb the tree. However, the next month (the last week of December) another farmer, Mr Robert Newberry, whose scrub paddock I had scoured, following up my instructions, found therein a Regent's nest containing a pair of fresh eggs, which I had the pleasure of describing before the Royal Society of Victoria on the 8th September 1892. The nest was placed in the scrub about 15 feet from the ground, and was observed by the bird sitting thereon. The structure was of such a loose nature—merely a few twigs, etc., forming a flat shelf—that it fell to pieces on removal from the tree.

One evening we discovered a bower on the ground, underneath thick scrub, and a small bird gaily tripping through. It was perfect, but not so large as those usually built by other bower-building birds, being only 7 inches or 8 inches high, with walls 7 inches broad at the base, and an average width inside of 3½ inches. After much difficulty a photograph was taken of the interesting structure.

BOWER OF REGENT-BIRD.

From a Photo by the Author. *From the "Australasian."*

Regent-Birds being frugivorous, are very destructive to the fruit crops of the selectors, and, like many other fruit-eating birds, are very partial to the black, juicy berries of the inkweed (*Phytolacca*), an introduced plant, which flourishes breast-high in nearly every clearing throughout the district.

On questioning the aboriginals (Richmond River tribe) about the Regent-Bird, they called it "Selgun," which

means the sun, and has reference no doubt to the bird's splendid yellow plumage.

A second pair of Regent-Bird's eggs found by another farmer fell to my collection. They were taken from a nest situated in a Buoyong sapling about 12 feet high, in scrub—Date, 30th November 1896. I was fortunate in this instance in having the nest likewise forwarded to me.

NEST AND EGGS OF REGENT-BIRD.
From a Photo by the Author.

It often happens when once a rare bird's nest and eggs have been discovered, many such nests are afterwards found. Mr Henry R. Elvery, Alstonville, Richmond River, has kindly sent me original notes of three Regent's nests he found during the season 1896-97.

Mr Elvery says:—"At the beginning of November 1896, I was looking for nests on the edge of a standing scrub, when I noticed a bird fly into a prickly tree. On approaching I saw that the bird was building, the nest being nearly complete. I took up a convenient position and watched the bird fly to and from the tree several times, and did not leave

until I was convinced the bird was a female Regent (*Sericulus melinus*). The tree in which the nest was built was small but very thorny, and I could see there would be difficulty in getting the nest.

"When I thought the nest might contain eggs, I climbed up a larger tree near, to the height of a few feet above the nest, which I could not plainly see for the mass of intervening prickly branches, but I managed to ascertain it contained at least one egg.

"Two days later, on the 16th November, I visited the place at dusk, having with me a tomahawk, a pruning knife, and a pair of climbing irons, such as are used for climbing telegraph poles. As I approached the tree, the bird flew from the nest, therefore I knew that the full clutch had been laid. The nest was about 25 feet from the ground, and on the tree in which it was placed was growing a bunch of "Lawyer" vines (*Calamus*). I climbed the first distance up a pole, which I placed against the tree, cutting my way up through the thorns as I went, and thus reached the head of the tree. The nest was an open structure of dry twigs, and I could now plainly see the eggs through the bottom of the nest. I then cut away the intervening branches before I could get my hand through to the nest, which contained three eggs. Placing two in my hat and one in my mouth, I reached the ground safely."

On the 19th December Mr Elvery found another nest containing two eggs nearly fresh. This nest was built in the head of a bush, around which was growing a mass of "Lawyer" vines, and was about 12 feet from the ground. On the 13th January following, he found a third Regent's nest containing a pair of eggs. Nest and eggs together with the hen bird, which Mr Elvery shot, were presented to the Australian Museum, Sydney.

Breeding months, November, December, and January.

PRIONODURA NEWTONIANA, De Vis.

Golden Bower-Bird.

Figure.—Sharpe, Birds of Paradise, part i. pl. 7.
Reference.—De Vis, P.L.S., N.S.W., vol. vii. p. 582.
Description of Eggs.—De Vis, Report Scientific Expedition to Bellenden-Ker Range, p. 87 (1889).

Geographical Distribution.—North Queensland.

Nest.—Cup-shaped, and loosely constructed of fibrous roots, lined with finer material of the same kind, and decorated with a little green moss on the outside (De Vis).

Eggs.—Clutch (?); pale yellowish-grey, profusely freckled and blotched with pale brown. Dimensions:—27 mm. (1·06 inch) by 19 mm. (·74 inch) (De Vis).[1]

Observations.—This, the last-discovered species, and one of the most beautiful of bower-building birds, vying in its golden splendour the Regent-Bird, shares the shades of the northern scrubs of Queensland with its curious cousin, the Tooth-billed Cat-Bird (*Scenopœus dentirostris*).

I cannot do better than give the discoverer's (Mr K. Broadbent) own interesting remarks of this rare and beautiful species, as read before the Natural History Society of Queensland:—

"Newton's Bower-Bird (*Prionodura newtoniana*).—This bird was first obtained by me in September 1882 in the Tully River scrubs, though I only secured then an immature specimen, coloured uniformly olive brown upon the upper surface. This—the type—Mr De Vis described.

"Whilst pursuing my official duties at Herberton in the months of March to May 1889, I met with several examples of a bird that I at once detected to be Newton's Bower-Bird, and amongst them some gaily-coloured, full-plumaged cocks, which, instead of exhibiting the sombre hues of youth, are largely bright yellow coloured, they being, as it is said, 'one

[1] Although I have given Mr De Vis's description of the nest and egg, which appear to be taken from specimens furnished by Mr Archibald Meston, I have no doubt in my own mind they are referable to some other bird—possibly the Fly-Robin (*Heteromyias*), and not to the Golden Bower-Bird.

of the three handsomest birds in Australia.' This rediscovery on my part was announced in an official communication dated from Herberton, 30th March 1889.

"At the commencement of February of the same year, Mr A. Meston, during his first exploration of Mount Bellenden-Ker, procured a single specimen of a very handsome bird, which, at its receipt at the Museum on the 25th March, was pronounced to be a new bird, and, as such, received the name of Meston's Bower-Bird (*Corymbicola mestoni*); my discovery that it was only the full-plumaged male of Newton's Bower-Bird (*Prionodura newtoniana*), and the specimens and written observations which I forwarded in support of this conclusion not having been then received in Brisbane.

"These observations, as some others due to Mr Meston, are to be found in a paper entitled, 'A Further Account of *Prionodura newtoniana*,' by C. W. de Vis, contained in the sixth volume of the *Proceedings* of our Royal Society, and may be fittingly quoted on this occasion:—'*Prionodura* is emphatically a Bower-Bird. Both its observers in nature met with its bowers repeatedly, and agree in representing them to be of unusual size and structure. From their notes and sketches it would appear that the bower is usually built on the ground between two trees, or between a tree and a bush. It is constructed of small sticks and twigs. These are piled up almost horizontally around one of the trees in the form of a pyramid, which rises to a height varying from 4 feet to 6 feet A similar pile of inferior height—about 18 inches, is then built around the foot of the other tree. The intervening space is arched over with stems of climbing plants, the piles are decorated with white moss, and the arch with similar moss, mingled with clusters of green fruit resembling wild grapes. Through and over the covered run play the birds, young and old, of both sexes. A still more interesting and characteristic feature in the playground of this bird remains. The completion of the massive bower so laboriously obtained is not sufficient to arrest the architectural impulse. Scattered immediately around are a number of dwarf, hut-like structures—

gunyahs they are called by Broadbent, who says he found five of them in a space of 10 feet diameter, and observes that they give the spot exactly the appearance of a miniature black's camp. These seem to be built by bending towards each other strong stems of standing grass, and capping them with a horizontal thatch of light twigs. In and around the gunyahs, and from one to another, the birds in their play pursue each other to their heart's content.'"

Mr Broadbent mentions that the male Golden Bower-Bird is a splendid mocker, imitating all the birds of his locality, as well as the croaking noise of tree-frogs. The note of the female resembles that of the Queensland Cat-Bird (*Æluroedus*) in a sharper and shriller key.

Mr Broadbent has thoughtfully sent me his original sketches of various playing-places of the Golden Bower-Bird (*Prionodura newtoniana*), which he made when he accompanied Mr Meston's scientific expedition to Bellenden-Ker in 1889, and when additional specimens of the beautiful birds themselves were obtained.

Sketch 1.—Bower made of small sticks, decorated with long white moss and little bunches of wild fruit resembling grapes. Locality, 7 miles from Herberton. Found, April. This illustration shows the base of two small trees, heaped about with a larger pyramid of fine sticks (the trees having the appearance of growing out of the heap), with a smaller semi-detached heap on the right-hand side.

Sketch 2.—Bower 8 feet high, decorated with long white moss off pine trees, and wild grapes. Locality, Herberton Scrub, 20th May. In this instance the sticks are piled in pyramid form around a single small tree or sapling for about two-thirds of its height, with a smaller heap about 1½ foot high on the left side.

Sketch 3.—Bower seen Herberton Scrub 14th May. This is exceedingly interesting, and represents a double pile of small sticks—one 4½ feet high around the stem of two thin sapling trees, the other 1½ foot high to the right around the base of a large tree.

Sketch 4.—This sketch merely shows a large tree with its

spur or root on the right, ornamented with portions of small sticks. Herberton Scrub, May.

Sketch 5.—Depicts a play-ground with two miniature "humpy"-like structures, built with growing ferns, roofed over with small twigs. Five or six of these little arbour-like places, which are about 10 inches high, belong to one play-ground. Herberton Scrub, May.

III. *The Summer Birds of the Summer Islands.* By J. B. Dobbie, F.R.S.E., F.Z.S., M.B.O.U.

(Read 19th January 1898.)

The Summer Islands form a group of some thirty small islets lying in outer Loch Broom. They are most easily reached from Achiltibuie, West Ross-shire, where good sailing-boats can be had. Tanera More, which is the largest of the group, is only about 2¼ miles distant from Achiltibuie; while Priest Island, the most remote of all, is about 7¼ miles from that starting-point.

With the exception of Tanera More, these islands are uninhabited. Tanera More is rather more than a mile and a half long, and not quite one and a quarter mile broad. It supports a population of over a hundred souls. We know, however, from the "Statistical Accounts," that some of the other islands were formerly inhabited; and on Priest Island there are still to be seen traces of human dwellings.

The Summer Islands are, with hardly an exception, rugged and precipitous. They, no doubt, owe their singularly inappropriate and misleading name to the circumstance that in summer they are used by the crofters as feeding-grounds for a few cattle and sheep. They are bleak and barren in the extreme, and those visited seemed incapable of supporting any but the hardiest forms of vegetable life. The two puny rowans on Priest Island were the only apologies for trees which we observed on the whole group of islands. The caves are, as a rule, decorated with sea-spleenwort; while the unsightly lochs on Priest Island have their presence

almost redeemed from ugliness by the yellow iris, which grows in abundance on their margins.

Mr Harvie-Brown visited Priest Island on 4th July 1884, on which occasion he observed eighteen different species of birds. So far as I am aware, this contribution, which appeared in the *Transactions of the Norfolk and Norwich Naturalists' Society*, is the only account of the avifauna of the Summer Islands which has hitherto been published. The following list of the birds observed in these islands in June last by my friend the Rev. Mr Bonar and myself may therefore be of some small interest. It does not, of course, by any means profess to be complete, even so far as the islands visited by us are concerned. We did not land on Tanera More, the largest island of the group, for the reason that it is inhabited, and therefore little likely to afford good results to an ornithologist.

In company with Mr Bonar I visited Priest Island, Glasleacbeag, Eilean Dubh, Horse Island, and Carn-nan-Sgeir. After I had returned south my companion visited Bottle Island, Carn Deas, Sgeirean Glasa, Glasleac Mor, Eilean Fada Mor, and Tanera Beg. We had fully determined to spend a night on Priest Island, with the object of trying to discover whether or not the Stormy Petrel breeds there; but our landlord could not be persuaded to give us the services of the ghillies or the use of his boat for such a purpose, and we had therefore to abandon the project.

1. Turdus musicus, Linn.

(Song Thrush.)

One or two seen on Priest Island by Mr Harvie-Brown. We failed to observe the bird when we visited that island, though no doubt it still breeds there.

2. Saxicola œnanthe (Linn.).

(Wheatear.)

Found nesting on every island visited by us. At least three pairs breed on Priest Island.

3. Troglodytes parvulus, K. L. Koch.

(Wren.)

Three individuals of this species were noticed on Priest Island. We flushed them simultaneously from out the tall heather near one of the small lochs, and, in all probability, two pairs at least nest on the island. I did not observe the bird on any other of the Summer group. It is not included in Mr Harvie-Brown's list of the birds seen by him on Priest Island.

4. Anthus pratensis (Linn.).

(Meadow Pipit.)

A pair seen on Priest Island; a nest containing four eggs found on Horse Island.

5. Anthus obscurus (Lath.).

(Rock Pipit.)

Breeds plentifully on every island visited.

6. Emberiza miliaria, Linn.

(Corn Bunting.)

While sailing close to Tanera More we heard the unmistakable song of this species. We never observed the bird on any of the islands visited, for the good reason that none is inhabited.

7. Sturnus vulgaris, Linn.

(Starling.)

Abundant. I have no note of having observed it on Glasleacbeag; but several pairs nest on Priest Island, Glasleac Mor, Bottle Island, and Eilean Dubh.

8. Corvus corax, Linn.

(Raven.)

A pair nest regularly on a cliff in Horse Island. The nest was pointed out to us. While exploring this island we

saw a Raven, no doubt one of the owners of the nest, examining the ground systematically in quest of food. I found on Priest Island a dead Raven at the foot of the cliff which is tenanted by the Peregrine Falcon.

9. CORVUS CORNIX, Linn.

(Hooded Crow.)

Several seen on Horse Island, Carn-nan-Sgeir, Eilean Dubh, and Tanera More; and it probably breeds on nearly all the islands.

10. ALAUDA ARVENSIS, Linn.

(Skylark.)

Observed only on Horse Island, where it nests.

11. FALCO PEREGRINUS, Tunstall.

(Peregrine Falcon.)

A pair nest on Priest Island. After some little trouble Mr Bonar discovered the eyrie, which contained four young birds about a week old. Their larder was very well stocked, and contained the head of a Redshank, a bird which was not observed on any of the Summer Islands.

Upon landing at Glasleacbeg we found that the island had been visited by some large raptorial bird. A very powerful freebooter it must have been, as was proved by the numbers of skulls and wings of Black-backed Gulls which we found lying about. The depredations were probably caused by the Peregrines from Priest Island. Indeed it is difficult to lay them to the charge of any other bird. On the other hand, the castings were large for those of a Peregrine—at all events they were much larger than any which had previously come under my observation. Moreover, it does seem strange that the Peregrines should prey upon such large and powerful birds as the Black-backed Gulls, when they could, by attacking incomparatively weaker quarry, obtain an abundant food-supply.

Mr Bonar thinks that the Peregrine's eyrie on Priest Island has within the last two years been removed farther west along the cliff. The cause of this change is doubtless the great increase in the number of the Cormorants which nest on its eastern part.

12. Phalacrocorax carbo (Linn.).

(Common Cormorant.)

Very abundant, nesting in huge numbers on Priest Island. There are also fairly large colonies on Eilean Dubh and Tanera Beg, while a few pairs breed on Glasleac Mor. Mr Harvie-Brown in 1884 estimated the number of pairs which nested on Priest Island at one hundred and thirty. The colony has at least doubled its numbers since his visit; and I should say that not less than three hundred pairs frequented the island for nesting purposes last summer. According to Mr Bonar's computation, the two colonies on Tanera Beg contain at least fifty nests each. On Priest Island the Cormorants nest on an inland cliff and not on precipices by the sea, the reverse being the case with the Shag. On the other islands visited by us on which both birds nest, we found that the Cormorants bred near the top, and the Shags near the bottom of the cliff.

13. Phalacrocorax graculus (Linn.).

(Shag.)

Abundant. Nests in large numbers on Priest Island, Tanera Beg, Eilean Dubh, Glasleac Mor, and Bottle Island, and also in smaller numbers on the adjoining mainland. This bird breeds only on precipices by the sea, and I never saw one nest which could be reached without very considerable risk. Very few eggs were observed until the last week of June. On the 18th of that month Mr Bonar found a great many incomplete nests, while on the 25th not a single young bird had been hatched in either of two large colonies which he visited.

14. Anser cinereus, Meyer.

(Grey-lag Goose.)

Common. We observed 7 on Glasleacbeg, 11 on Priest Island, and 5 on Eilean Dubh. Their droppings were found in great profusion scattered all over these islands, and this circumstance shows that they are regularly visited by this species. Mr Harvie-Brown considers it probable that this bird nests on Glasleacbeg. On the other hand, Mr Bonar, a ghillie, and myself searched Glasleacbeg, as well as Priest Island, most carefully, but failed to discover any traces of its nest, and I am strongly of opinion that the Grey-lag Goose does not nest on any of the islands, and that it only resorts to them for feeding purposes.

15. Tadorna cornuta (S. G. Gmel).

(Common Sheld Duck.)

One observed close to the shore while sailing near Tanera More. Mr Bonar is of opinion that he saw a pair with two young off Eilean Fada Beg, but as he had no binoculars with him, he is not quite certain of his identification.

16. Anas boscas, Linn.

(Mallard.)

Mr Harvie-Brown observed one on Priest Island in July 1884, where one was also seen by Mr Bonar in September 1895.

17. Mergus merganser, Linn.

(Goosander.)

An egg, which had probably been hatched, was found by Mr Bonar on Glasleac Mor, and the inference is that the Goosander breeds on that island. I saw no trace of the bird on any of the islands visited by me, but it is common on the adjacent mainland.

18. Mergus serrator, Linn.

(Red-breasted Merganser.)

One seen swimming off Eilean Fada Mor.

19. Columba livia, J. F. Gmel.

(Rock Dove.)

This bird, though found on most of the islands on which we landed, is nothing like so common as one would expect it to be, considering the locality is so well suited to its requirements. The very remarkable fissure in Tanera Beg is one of its breeding-haunts, but even there we saw very few pigeons. Mr Bonar explored a cave in Eilean Dubh frequented by the Rock Dove, but saw only four.

20. Hæmatopus ostralegus, Linn.

(Oyster-Catcher.)

Exceedingly abundant—perhaps the very commonest bird found on these islands. It nests in every one of them visited by us.

21. Totanus hypoleucus (Linn.).

(Common Sandpiper.)

One seen on the shore of Tanera More, where, no doubt, the bird nests. One Sandpiper was observed by Mr Harvie-Brown on Priest Island.

22. Totanus calidris (Linn.).

(Common Redshank.)

We found the head of a Redshank in the Peregrine's eyrie on Priest Island. I never saw or heard the bird on any of the Summer Islands or on the peninsula of Coigach.

23. Numenius arquata (Linn.).

(Common Curlew.)

Several observed on Horse Island, where it undoubtedly nests.

24. Sterna macrura, Naum.

(Arctic Tern.)

On the 7th June we visited Carn-nan-Sgeir, where, as our ghillies informed us, the Terns nested in considerable numbers. On our way thither we landed on Horse Island, on which we observed at least thirty. To our great astonishment, however, we found not the slightest trace of its nest, or of the bird itself, on Carn-nan-Sgeir. Our ghillies concluded that the Terns had been compelled by ruthless persecution to abandon the island. Towards the end of the month Mr Bonar observed large flocks of Terns flying in the direction of this island, and he believes that these birds still breed there, but that the time of our search was too early to permit of us obtaining nests. The Arctic Tern, however, certainly nests on Glasleac Mor, but that was the sole island of the group from which we obtained eggs.

25. Larus ridibundus, Linn.

(Black-headed Gull.)

A pair of these birds were observed by Mr Bonar in Baden Bay, and on the same day he saw several following the plough at Auchnahaird.

26. Larus canus, Linn.

(Common Gull.)

Very common, nesting in large numbers on many of the islands. In every case I found that this Gull breeds on these islands on the bare rock, and never among heather. A Gull belonging to this species had her nest, which

evidently contained young, far down a cliff at Eilean Dubh, and right on the only track accessible even for a goat. A goat with her kid were making their way along this path, when their progress was stopped by the Gull, who, each time they advanced, dashed at the intruders with outspread wings and screaming hoarsely. We waited quite half an hour watching the proceeding, and I was delighted to find that the gallant bird made good her defence to the end. Though not included by Mr Harvie-Brown in his list of birds of Priest Island, the Common Gull nests there in considerable numbers.

27. Larus argentatus, J. F. Gmel.

(Herring Gull.)

Fairly common, though not nearly so abundant as the Common or Lesser Black-backed Gull. I observed quite a large number both on Priest Island and Glasleacbeg, and it no doubt breeds on both. I found its nests only on Horse Island and Eilean Dubh, where it almost invariably breeds on the cliffs along with the Common Gull. Mr Bonar, however, obtained its eggs from Sgeirean Glasa.

28. Larus fuscus, Linn.

(Lesser Black-backed Gull.)

By far the most abundant Gull found in these islands. It breeds in large numbers on Glasleacbeg, Priest Island, Horse Island, Eilean Dubh, and Glasleac Mor, and, without doubt, on several of the other islands, such as Tanera Beg and Tanera More. The nests we found were invariably placed in the heather.

29. Larus marinus, Linn.

(Great Black-backed Gull.)

Common. It nests on Glasleacbeg, Glasleac Mor, and Priest Island, the first named of these containing the largest

colony. On the 4th June we found most of the nests on Glasleacbeg contained young, while, on the same day, I did not see a single egg on Priest Island, although many young birds were noticed.

30. Rissa tridactyla (Linn.).

(Kittiwake.)

Mr Bonar is quite certain that he saw a pair of these birds diving in their characteristic manner in Baden Bay. I never observed the bird anywhere during my stay in West Ross-shire, where it is undoubtedly very rare.

31. Alca torda, Linn.

(Razorbill.)

Found commonly in flocks and in company with Guillemots. Mr Harvie-Brown saw a very few pairs in a crevice on the east shore of Priest Island, where it no doubt nests. It certainly does so on Bottle Island, for, on the 25th June, Mr Bonar obtained two eggs, one hard-set, from a cliff on the south-western shore, where he found a colony. As the loftier nests were inaccessible, my companion could not form an accurate opinion of the number of pairs which bred there. From the number of birds which flew out on the approach of the boat, it is probable that the colony numbered more than a dozen pairs. I am inclined to think that the Razorbill also nests on Eilean Dubh.

32. Uria troile (Linn.).

(Common Guillemot.)

Very abundant. When sailing to and from the Summer Islands, we invariably saw very large flocks of these birds, usually mixed with Razorbills. We were unable to discover the Guillemots nesting in any of the Summer Islands though

we are both persuaded that they do so on the western cliffs of Priest Island, which we were unable to visit.

33. Uria grylle (Linn.).

(Black Guillemot.)

Very common, and found nesting in more or less abundance on Priest Island, Tanera Beg, Eilean Dubh, Glasleac Mor, Bottle Island, and Carn Deas. This bird is stated by all authorities whom I have consulted to deposit its eggs on the bare ground; and Saxby affirms that though he has found them 50 or 60 yards inland, on grassy slopes strewn with rocks, he never found them in anything like a nest. On the other hand, Mr Bonar never, in one single instance, out of the many found by him, observed the eggs of this species deposited on the bare ground. Without exception the eggs were resting on small gravel, which had probably been carried thither by the bird. In one instance, fragments of bones bleached by the rain were used, along with the gravel, to form the receptacle for the eggs. He was so greatly impressed with this interesting discovery, that he took particular care to examine every nesting-site of this bird which came under his observation. One of our ghillies climbed to a nest on Glasleac Mor, and reported that the eggs were placed on the bare rock; but, having been asked to look more carefully, he ascertained that the bird had laid on a layer of small pebbles. We are, moreover, of opinion that the gravel is carefully selected by the parent birds, for round and round the eggs it was all of one size—indeed, it may be described as being just the size of that employed by the Oyster-Catcher for lining the hollow of its nest. Furthermore, in several cases a slight hollow had been made by the sitting bird.

Mr Bonar, on 18th June, found on Glasleac Mor a nest of the Black Guillemot which contained three eggs; but it by no means follows that they are the produce of one and the same bird—indeed, I am strongly of opinion that they are not.

34. Fratercula arctica (Linn.).

(Puffin.)

Fairly common, and nests on both Bottle Island and Eilean Dubh. The Puffin is also a late breeder in these parts, for when I visited the latter island on the 7th June, I never even saw the bird; while on the 25th Mr Bonar found it nesting in burrows in close proximity to a colony of Shags.

35. Procellaria pelagica, Linn.

(Storm-Petrel.)

On the 4th June I found a wing of this bird on Glasleac-beg, and a few minutes afterwards my companion obtained the head with the other wing attached. There is therefore a strong probability that the bird nests on that island.

Such is the concise account of our exploration of the avifauna of the Summer Islands during the month of June 1897. I need hardly submit that our sojourn in the district was so short that we could not expect important results. The poverty of the list is striking; nevertheless, poor as it is I am of opinion that, so far as breeding species are concerned, it is not likely to be largely augmented. My conclusion, therefore, is that during the nesting-season these islands offer little attraction to ornithologists. In autumn the case may be different; but even if they lay on the great migration route, the Summer Islands do not possess a food-supply sufficient to make them specially attractive.

As may be inferred from my numerous references to him, I am largely indebted to my friend, the Rev. Mr Bonar, for material. That gentleman's much longer stay in the neighbourhood and his comparatively long acquaintance with it, rendered his assistance of exceptional value.

IV. *On the Influence of Muscular Attachments in producing Modifications of the Popliteal Surface of the Femur, and Alterations in the Diameters of the Shaft of that Bone in the Popliteal Region.* By DAVID HEPBURN, M.D., C.M., F.R.S.E., Lecturer on Regional Anatomy, University of Edinburgh.

(Read 16th March 1898.)

Recent observations have shown that the long bones of the human body present characters which in many ways are as indicative of race and sex as those which are obtained from the examination of the apparently more important cranium. Thus, observations made by Dwight (1) of Boston, Dorsey (2) of Chicago, and by myself (3) have practically proved that the diameter of the head of the humerus, femur, or tibia provides an almost certain indication of the sex of the individual to which the bone belonged. On the other hand, Sir William Turner (4), Manouvrier (5), Scott (6) of Dunedin, and myself have published observations which show that the shaft of the femur in its upper, middle, and lower thirds presents features which to a large extent provide race characteristics. Apart from these considerations, the human femur presents characters by which it may readily be distinguished from the femora of those anthropoid apes which most nearly resemble man. Clearly, therefore, it becomes a matter of much importance to study those conditions which may modify the surface contours, or materially alter the diameters of this bone.

The general proportions of the femur are doubtless determined by the functions which it requires to fulfil in the economy of the human body, and in certain respects these are remarkably constant, for, as I have elsewhere shown (3), there is almost a constant mechanical proportion between the average diameter of the femoral head and its average bicondyloid diameter, a proportion which may be expressed as the ratio of 1 to 1·7, and which probably bears a direct relationship to the erect attitude of man. As regards the shaft of the femur, its antero-posterior and transverse

diameters in the upper, middle, and lower thirds must bear definite relations to the strains which it is called upon to sustain. Nevertheless, in the upper or platymeric, and in the middle or pilastric sections of the shaft, there is ample evidence to show that not only the special surface contours of the bone, but its antero-posterior and transverse diameters, may be definitely modified by the size and extent of the muscular attachments. Taken by itself, the ridge or elevation which marks the precise attachment of a muscle may not appear very important, but the accumulated influence of these attachments is sufficient to produce marked differences in various diameters of the bone. The recognition of this principle is of the utmost importance, more especially when we have to deal with unusual variation in the proportionate diameters of long bones. The occurrence of such unusual proportions between the antero-posterior and transverse diameters of the popliteal section of the femur, together with the pronounced convexity of the popliteal surface of the Trinil femur, led Dr Dubois (7) to claim a unique and specific value for these appearances. I have elsewhere shown (8) that the peculiar characters of the Trinil femur are by no means uncommon among the femora of different races of mankind; but as my observations were restricted to macerated specimens, the importance of testing them by dissections cannot be overestimated. For this purpose the present paper records the dissection of a popliteal space in which certain muscles afforded noteworthy variations from their normal attachments. The measurements of the two macerated femora from this individual are also recorded, for purposes of comparison.

It may be well to note at this stage that muscular abnormalities in connection with the human popliteal space are by no means common, and that the general arrangement of this space in the gorilla and orang does not differ in any essential particular from the conditions found in man, whereas in the chimpanzee (9) the popliteal surface of the femur is almost entirely covered by the insertion of the pubic or obturator portion of the adductor magnus muscle,

while in the gibbon the two vasti muscles are permitted to approximate to each other at the upper end of the popliteal space by reason of the restricted insertion of the adductor magnus, and the similarly curtailed origin of the femoral head of the biceps flexor cruris.

The limbs were those of an adult female subject in process of dissection in the Practical Anatomy Room of the University of Edinburgh. The following appearances were noted in the right lower limb:—

Adductor Magnus Muscle.—The rounded tendon of insertion of the ischial segment of this muscle became fused with the internal supracondyloid septum, close to the termination of the femoral artery. This union was maintained as far as the internal condyle of the femur, into the inner surface of which the tendon was inserted between the adductor tubercle and the origin of the inner head of the gastrocnemius muscle. The fleshy insertion of the pubic section of the muscle was continued downwards from the lower end of the linea aspera to the popliteal surface of the femur, and extended on the inner side of the vertical mid-popliteal line to a point 4·5 cm. from the margin of the intercondyloid notch. Some fibres of this part of the muscle were inserted into the posterior aspect of the internal supracondyloid septum, under cover of the commencement of the popliteal artery, and thereby an oval opening 4 cm. in length was formed for the transmission of the vessels from the inner side of the thigh to the popliteal space. This opening was therefore situated within the adductor magnus muscle, rather than in an interval between the respective insertions of its fundamental pubic and ischial segments. Moreover, the vessels were separated from direct contact with the shaft of the femur by the interposed muscular fibres.

Biceps Flexor Cruris Muscle.—The short or femoral head of this muscle had a very extensive origin. In addition to its attachment to the linea aspera, it extended as high as the gluteal impression, while inferiorly its origin from the external supracondyloid ridge and septum reached to within 6·5 cm. of the intercondyloid notch.

Gastrocnemius Muscle.—This muscle presented three heads of origin:—The *inner* head arose from the popliteal surface of the femur close above the internal condyle; from the upper and back part of the same condyle; from the posterior aspect of the tendon of the adductor magnus, and from the adjacent part of the supracondyloid ridge and septum. The *middle* head arose by a distinct tendon attached to a tubercle on the popliteal surface of the femur, situated immediately above and to the outer side of the origin of the inner head. The upper limit of this origin was 2 cm. distant from the lower end of the fleshy insertion of the adductor magnus. After an independent course of about 5 cm., this small slip joined the inner head. The *outer* head arose with the plantaris muscle

from the outer and upper aspect of the external condyle, but not from the popliteal surface; to a slight extent from the lower end of the external supracondyloid septum; while some of the fibres of the plantaris arose from the superficial surface of the tendon of the gastrocnemius. Neither of these origins extended above the level of the condyle, on which they passed so far forward as almost to appear in front of the lower end of the supracondyloid ridge.

The immediate effect of the extension of the adductor magnus muscle into the popliteal space, and the presence of a middle head to the gastrocnemius, was to disturb the relation between the popliteal artery and vein, for in directing its course to the middle line of the popliteal space, the artery became separated from the vein by the interposition of the middle head of the gastrocnemius.

In the left limb, the attachments of the adductor magnus and biceps flexor cruris were almost identical with those found in the right limb, but as regards the gastrocnemius and plantaris muscles, their points of origin were normal. After the two femora were macerated, they yielded the following measurements:—

Collection,	University of Edinburgh.	
Sex,	Female.	
Age,	Adult.	
	Right.	Left.
Total oblique length,	440	440
Diameter of femoral head,	46	46
Diameters of sub-trochanteric region—		
Antero-posterior,	24	24
Transverse,	30	31
PLATYMERIC INDEX,	*80*	*77·7*
Diameters of middle region of shaft—		
Antero-posterior,	28	28
Transverse,	26	27
PILASTRIC INDEX,	*107·6*	*103·7*
POPLITEAL INDEX,	*75·6*	*72·5*
(i) Popliteal width at 4 cm.,	37	39
(u) Maximum bicondyloid width,	76·5	77
$u = 100, \frac{i \times 100}{u} =$	*48·3*	*50·6*
Distance of linea aspera from external condyle,	100	89
"mn,"	30	29
"mp,"	28	27·5
Distance of nutrient foramina from lower end of femur,	165-282	175

I must confess that the examination of these figures was somewhat of a disappointment to me, for I fully expected to find marked alterations in the popliteal diameters of the bones, in view of the pronounced muscular abnormalities which they presented. But this is not the case. In spite

of the fact that the eye can see distinct ridges corresponding to the attachments of the abnormal muscles, yet neither the diameters nor the popliteal index which is calculated from them appear to have been materially affected. This seems all the more remarkable since those sections of the shaft where the platymeric and pilastric indices are calculated are considered to be definitely affected by the action of the muscles attached to them.

In the femora under consideration both popliteal indices are comparatively low, in fact they are among the lowest which I have been able to record (3) from modern British female femora, in which my recorded average popliteal index is 78·25. My recorded average for both sexes is 78·1, with a range of variation from 66 to 89·7. It is true that the femur in which the muscles were most markedly abnormal presents the higher index, but I do not attach much value to this slight difference, for among many femora taken from many diverse races of mankind I have only found one male Lapp, one male Bushman, and one female Eskimo, in whom the two femora yielded the same index. Among the very few anthropoid apes which I have had the opportunity of examining (3), the two femora of the same individual gave a similar index in the case of one orang-outan and two chimpanzees.

It seems to me, therefore, that we cannot attribute great modifications of the femoral diameters in the popliteal region to the results of muscular attachments. It is difficult to imagine that any of the muscles attached to the femur in the popliteal region could ever attain such proportions as would account for the high popliteal indices of many femora. In one femur of an Australian aboriginal, I have recorded (3) a popliteal index of 96·9, a figure which indicates that the shaft was almost cylindrical in the popliteal region. This ne very high index (96·9), with the associated convexity of popliteal surface of the femur, formed one of the most il u of the famous Trinil femur, and its dis- Dr Dub acting on my suggestion (7), felt inclined d on to a series of muscular attachments, carried the characters of the pilastric

section of the femoral shaft to a lower level than usual. In the femora under consideration a comparatively short popliteal surface was associated with exceptional attachments of the muscles, and yet none of the popliteal diameters were out of the ordinary.

I am therefore forced to conclude that convexity of the popliteal surface, and high popliteal indices, are not to be explained by an increase of the antero-posterior diameter caused by muscular attachments. In searching for a sufficient explanation of high popliteal indices, it is well to bear in mind that all varieties of platymeric, pilastric, and popliteal indices are compatible with the erect attitude, since they are all found in man; and, therefore, when muscular attachments will not account for the proportions of the femoral shaft, it is probable that they are merely mechanical adaptations for the resistance of strain in certain directions. The ordinary type of popliteal surface in European femora is one which is flat, or it may be slightly concave between the outer and inner supracondyloid ridges, and yet among rachitic specimens (8) a decided convexity of this surface may be present. Under normal healthy conditions some similar mechanical adaptation might be expected in the femora of those races which were characterised by the peculiar race attitude of "sitting on their heels," and in this connection it is interesting to note that I have found the highest average of popliteal indices among the femora of aboriginal Australians, Hindoos, Kaffirs, and Bengalees.

At the same time we must not lose sight of the fact that it is permissible to regard a highly convex popliteal surface in the light of a historical reversion to the mechanical proportions which characterise the femora of the gibbon. In this anthropoid ape the upper part of the lower third of the shaft of the femur undoubtedly presents cylindrical proportions, which, however, disappear in the proximity of the knee-joint. If we accept the hypothesis of Dr Dubois that a gibbon-like ape was the direct progenitor of *homo sapiens,* then the Trinil femur might very readily be that of *Pithecanthropus erectus* and femora with great convexity

of the popliteal surface, merely reversions to the type of this primitive ancestor.

Still, however much speculations may assist us in the elucidation of difficult problems, they do not possess the value of evidence, and although we may conclude that the action of muscular attachments is insufficient to account for the condition, yet further proof of its causation requires to be produced.

In the foregoing text, reference has been made to the following papers:—

1. DWIGHT, "The Range and Significance of Variation in the Human Skeleton," *Boston Medical and Surgical Journal*, July 1894.
2. DORSEY, "A Sexual Study of the Size of the Articular Surfaces of the Long Bones in Aboriginal American Skeletons," *Boston Medical and Surgical Journal*, July 22, 1897.
3. HEPBURN, "The Platymeric, Pilastric, and Popliteal Indices of the Race Collection of Femora in the Anatomical Museum of the University of Edinburgh," *Jour. Anat. and Phys.*, October 1896.
4. TURNER, *Challenger Reports*, part xlvii., 1886.
   TURNER, *Journal of Anatomy and Physiology*, vol. xxi. p. 488, 1887.
   TURNER, "On Human and Animal Remains found in Caves at Oban, Argyllshire," *Proc. Soc. Antiq. Scotland*, 1895.
5. MANOUVRIER, "Étude sur les variations morphologiques du corps du femur dans l'espèce humaine," *Bull. Soc. d'Anthrop. de Paris*, October 1892.
6. SCOTT, *Transactions of New Zealand Institute*, 1893, vol. xxvi.
7. DUBOIS, "On *Pithecanthropus erectus*: a Transitional Form between Man and the Apes," *Trans. Roy. Dublin Soc.*, i., 1896.
8. HEPBURN, "The Trinil Femur (*Pithecanthropus erectus*) contrasted with the Femora of Various Savage and Civilised Races," *Jour. Anat. and Phys.*, October 1896.
9. HEPBURN, "The Comparative Anatomy of the Muscles and Nerves of the Superior and Inferior Extremities of the Anthropoid Apes," *Jour. Anat. and Phys.*, vol. xxvi.

V. *On the Validity of* Pissodes validirostris (*Schoenh.*) *as a Species.* By R. Stewart MacDougall, M.A., D.Sc.

(Read 20th April 1898.)

Pissodes is a genus of beetles belonging to the section Rhyncophora, or Weevils, whose characteristic is the possession of a rostrum or proboscis.

Of the twenty or so species belonging to the genus, five are well-known forest pests, injurious to coniferous trees,[1] viz., *P. notatus*, *P. pini*, and *P. piniphilus*, which attack trees of the genus *Pinus*; *P. harcyniae*, which attacks the spruce; and *P. piceae*, whose host-plant is the silver fir. The two last are said not to be found in Britain.

Pissodes notatus (Fabr.), the small brown or white-spotted weevil, measures on an average a quarter of an inch. The posterior angles of its wrinkled prothorax project sharply, and its hinder edges show two sinuous excavations. Both the upper and under surface of the beetle are powdered with white scales. On the upper surface of the prothorax stand four well-marked white points, and a fifth on the scutellum. The elytra have two transverse bands of scales, one in front and one behind their middle. The front one, which is non-continuous at the suture, is yellowish on either side externally, whitish internally. The hinder band has almost the same coloration; it is broader externally than internally, and is continuous right across the elytra.

The larva is a fleshy, wrinkled, legless grub, with a brown scaly head, and strong gnawing jaws.

P. notatus is injurious chiefly in the larval condition. The female lays her eggs in holes, made by her proboscis, in the bark. The larvæ on hatching out tunnel upwards or downwards in the cambial region, a trail of brown bore-dust remaining to map out the path of the larva. When full fed, the grub gnaws out a hole in the outer layers of the wood, and in this hollowed-out bed, protected by a cover of sawdust

[1] A full account of the biology of these insects, with preventive and remedial measures, will be found in my two papers: "The Genus *Pissodes* and its Importance in Forestry," in the *Transactions of the Royal Scottish Arboricultural Society*, 1896; and "Ueber Biologie und Generation von *P. notatus*," in the *Forstlich-naturwissenchaftlichen Zeitschrift*, 1898.

and wood chips, the pupation stage is passed. The imago for emergence bores a circular exit-hole through bed-cover and bark. Young pines from four to eight years of age are the favourite breeding-places, but pines in the "pole-stage" are also frequented.

Many years ago, Hartig and Ratzeburg, in Germany, found the larvæ of a *Pissodes* in pine cones. Ratzeburg took for granted that the grubs were those of *notatus*, and this opinion was repeated in the books.[1] Later, Redtenbacher, after examination of the imago, chiefly because of a slight difference in the shape of the posterior corners of the prothorax in his specimens as compared with *notatus*, named the species that bred in cones *Pissodes strobili.*

This *Pissodes strobili* is synonymous with *Pissodes validirostris*, a name given by Gyllenhal, who described the species breeding in cones, in Schonherr's work "Ueber Rüsselkafer."

While working with Professor Pauly in Munich, I carefully compared the specimens named *Pissodes notatus* and *Pissodes validirostris* respectively, in the Munich collections, without satisfactory proof of their difference. Again, during a short stay in Tharand, Saxony, through the kindness of Professor Nitsche, I had opportunity to compare the specimens of both beetles, and still without satisfaction.

How much alike *notatus* and the so-called *validirostris* are, will be seen if I bring together in parallel columns the stated points of difference.

P. notatus.	*P. validirostris.*
Larger.	Smaller and of slighter build.
Posterior corners of prothorax acute-angled.	Posterior corners of prothorax right-angled.
The hinder edges of the prothorax show sinuous excavations.	The hinder edges of the prothorax only slightly sinuous
	Elytra flatter.
Longitudinal rows of dots on elytra, larger.	Longitudinal rows of dots on elytra, finer.
	More white spots along the suture.

[1] *E.g.*, "Der Forstschutz," by Professor R. Hess, p. 240.

Regarding these distinctions, I may say that "size" must go for nothing. I have both collected and bred specimens of *notatus* smaller than any I have seen of *validirostris.*

Coloration must also go as a distinction, for, apart from other colour variations which I have often found in *notatus, notatus* specimens have been procured with the suture of the elytra white-flecked. Practically, then, the main factor relied on by the systematist for distinction is the shape of the corners of the prothorax.

Where the morphological characters were so difficult to differentiate, it has always been a satisfaction to fall back on the biology, *notatus* being the form that bred in pine stems, and *validirostris* the form which bred in cones.

Yet there was no certainty, and the doubts were given expression to in Nitsche's recent great work[1] as follows:—"Fraglich erscheint es doch noch, ob dieser Zapfenbewohner nicht wenigstens oftmals *P. notatus* (Fabr.) ist. Die Bestimmung nahe verwandter arten dieser Gattung ist wegen der Veränderlichkeit derselben bezüglich der feinen Unterschiede in der Gestalt das Halsschildes, in der Skulptur und Beschuppung der Flugeldecken äusserst schwierig und unsicher. Die endgiltige Entscheidung muss erst weiteren Untersuchungen vorbehalten bleiben."

Having material during the summer of last year, I started an experiment which had for its object the proving, if possible, that *P. notatus* would breed in pine cones, and if so, the consequent possibility that *notatus* and *validirostris* are one and the same.

On 5th June 1897 I made an excursion to Longniddry, and collected some fresh pine (*Pinus sylvestris*) cones. The cones, which were perfectly free from injury of any kind, were about a year old. They had been pollinated in 1896, and would normally have shed their seed at the end of 1897.

Method of Experiment.—Knowing that *notatus* took between three and four months for its development, my difficulty was to prevent the cones from becoming so hard and dry as to render them unsuitable for breeding purposes. After several

[1] "Mitteleuropaischen Forstinsektenkunde," vol. ii. p. 401.

trials I adopted the following plan. I left the cone or cones attached to a small piece of the branch which bore them. Having filled a number of glass jars (7 inches high by about 3 inches in diameter) with water, I corked them with large flat corks in which I had bored holes. Through each hole I thrust the piece of branch which bore the cones, so that the cut end of the branch dipped into the water of the jar.

Several such jars with their cone-bearing branches I placed on a large square board, which carried several inches of soil. Into the soil I fixed stakes, and then enclosed all in a large covering of thin muslin. The stakes supported the muslin like a tent. Into the large free space I introduced some living *notatus* of both sexes. These beetles were introduced on 7th June.

Occasionally further to prevent too rapid drying of the cones, I watered them overhead, and I always took care that the cut ends of the branches remained sunk in the water, by refilling the jars as they lost water by transpiration or by evaporation.

The little tent I kept in a glass-house at the Royal Botanic Garden. The door of the house always stood open, and the house was never artificially heated. I was afraid to leave the tent exposed in the open, in case the wind should play havoc with the experiment.

Now and again on examination I noticed the beetles alive, and the characteristic proboscis punctures on twig and cone both, gave evidence of their feeding.

On 30th August I removed all the branches from the jars, and pulled off the cones. The pulled-off cones were placed under a bell-jar. They had quite lost their green colour and looked dry.

On dissecting away the bark from the twigs to which the cones had been attached, it was interesting to me to find a number of *notatus* larvæ and pupæ, proving that at any rate the *notatus* had bred. In quite a number of cases these larvæ and pupæ were below the water-line. The twigs had been dipping well into the water, and the grubs in their tunnellings had gone downwards, so that they were feeding and pupæ lying in beds below water.

On 6th October, when about to examine the cones, which since 30th August had been by themselves, I found a *notatus* crawling actively about on the inside of the bell-jar. I looked for and soon got the cone from which the beetle had issued, the round flight-hole marking it out from the others. On 7th October another *notatus* issued from a second cone, and on 13th October from another cone a third *notatus.* In the case of two of the cones, the exit-hole was near the middle of the cone. In the third, the exit-hole was near the base of the cone, close to the stack. This proved then that *notatus* does breed in pine cones.

Having pointed out how fluctuating and indecisive are the external characters which are made use of to distinguish *notatus* and the so-called *validirostris,* and having shown that they can be no longer separated in the biology, I would respectfully submit that the time has come when it should be considered whether it were not wiser and better to drop *validirostris* as a specific name, and to describe *notatus* as "*Pissodes notatus* which breeds in pines and pine cones."

In closing this communication, I wish to thank Professor Eckstein, of Eberswalde, for his courtesy in comparing for me specimens of *notatus* and *validirostris.*

VI. *Dr Heddle, M.D., F.R.S.E., Emeritus Professor of Chemistry at St Andrews. Born* 1828; *died* 19*th November* 1897. By J. G. Goodchild, H.M. Geol. Survey, F.G.S., F.Z.S., M.B.O.U.

(Read 15th December 1897.)

Matthew Forster Heddle was the younger son of Robert Heddle of Melsettor, Hoy, Orkney, where he was born in 1828. His ancestors on both sides were of Scandinavian descent: it was therefore to be expected that some of the most prominent characteristics of the Norsemen should manifest themselves in his person sooner or later in life. It is to the antecedents of his forefathers, quite as much as to the nature of the surroundings amongst which he passed his earlier days, that we may attribute many of the

characteristics which distinguished him in later life. From his boyhood he had been accustomed to wander amongst the dangerous precipices and lofty sea-cliffs of his native islands, of which it has been said that "there no man dies, for each one breaks his neck"; and he had, further, been early accustomed to trust himself alone in a small boat, in which he often traversed the wild seas of the Orkneys, or found his way from place to place along the dangerous coast-lines of those parts. Surroundings like these could not fail to leave a strong impress upon the character of any thoughtful and reflective youth; and those who knew Heddle in after life had no difficulty in tracing the development of many of his characteristics to the influence of these early surroundings. It was to these early associations that he owed much of his very strong self-reliance; his readiness, when need be, to face danger; his fondness for things mysterious, vast, and impressive; and, lastly, the development of a powerful bodily frame and a strong constitution.

From Orkney he went to school at the Edinburgh Academy. There he seems early to have distinguished himself by his readiness to do battle on behalf of his weaker school-fellows. One or two stories told about him while there showed him to have been possessed of considerable self-control, fortitude, and pluck. Some other stories connected with his life at the Academy are told in the well-known "Chronicles of the Canning Club," to which those interested in further details are referred.

After leaving the Academy, Heddle went to Merchiston Castle, where we have records of him in 1842, '43, and '44. While there he stayed with the genial author of "Rab and his Friends," to whose influence Heddle was wont to attribute his tastes for natural science, and much else that was good in the later years of his life. At Merchiston he helped to found a school Natural History Society, whose members energetically worked at the zoology and botany of the neighbourhood. Amongst those who were fellow-members with Heddle were Lauder Lindsay of Perth, Wyville Thomson, Lawson of Dalhousie College, Canada, Howden of Montrose, and others hardly less well known. It was

at this stage of his career that he seems to have begun to develop that propensity for collecting which became his most dominant characteristic in after life. He began, it is said, by collecting shells; and in the end he acquired, by this means, no inconsiderable knowledge of conchology. He also got together the materials for a good herbarium. It was an incident connected with this latter which determined in what direction his collecting instincts should lead him in after life. It is said that he had one day lent this herbarium to a friend, who, by an unfortunate accident while out driving, dropped the herbarium while he was crossing a stream, whereby the results of several years' work were utterly ruined. Heddle made up his mind, after this untoward accident, to collect no more things which could be so easily destroyed, and then straightway began to collect stones in their stead. The commencement of his geognostical work may be said to have dated from the period when that resolve was made.

About this time he entered as a medical student at the University of Edinburgh, and underwent that course of training which has always constituted one of the very best possible foundations for scientific work of almost any kind. At the conclusion of his medical course, he went to Germany to study Chemistry and Mineralogy, going first to Clausthal and then to Freiburg. Regarding Heddle in after-life as a geognoser, one cannot fail to perceive how the influence of the particular kind of teaching imparted to him at these seats of learning pervades much of what he thought and wrote. He returned to Edinburgh, and graduated as M.D. in 1851, taking as his graduation thesis "The Ores of the Metals."

Soon after taking his medical degree, he commenced practice in Edinburgh, somewhere in the neighbourhood of the Grassmarket. His reminiscences of this part of his life do not appear to have been altogether pleasant, and who that knows the neighbourhood and the people can wonder at that? The dismal and squalid nature of his surroundings, the low intellectual grade of the people amongst whom his lot, for the time being, was cast; the absence of any prospect

of obtaining more than the very smallest remuneration for the hard work he had to undergo, all seemed to combine to make him look forward to the time when he might escape from the duties of a profession which was evidently so uncongenial to his natural tastes and inclination. If I may judge from what I saw of Dr Heddle during a few years' fairly close acquaintance with him in the field, in the museum, in the study, and by his bed-side, I should say that Nature may have intended him for any one of many professions. He was pre-eminently adapted to become a first-rate actor; he would have made a clever lawyer; as a mechanician his talents showed themselves equally well; he was, as we all know, eminent as a mineralogist; he proved an excellent geognoser; but, assuredly, he did not possess that particular combination of special gifts and acquirements which leads to success in the medical profession. So Dr Heddle eventually turned his attention from medicine, and for the remainder of his life devoted it to chemistry and geognosy. It is well for the scientific world that he did so, for the line of work that he then elected to take led to his becoming one of the foremost mineralogists of his day.

In 1856, soon after the date of this resolve, he chartered a boat and went to Faroe, where he succeeded in collecting, from the decomposition-products of the Tertiary volcanic rocks there, an extensive collection of zeolites. By means of the numerous duplicates obtained on this occasion, he was enabled to effect advantageous exchanges with other mineralogists, and thus formed the nucleus around which gathered the large collection to be again referred to presently.

For several years he acted as assistant to Professor Connell, who held the Chair of Chemistry at the University of St Andrews; and all through Connell's long illness and absence from the Lecture-Room there, Heddle filled his place. When the professorship at last became vacant, which was the case in 1862, Dr Heddle succeeded to the post.

Dr Heddle filled the Chair of Chemistry at St Andrews for twenty years. He was very popular with the students, for many reasons, but chiefly because he was an admirable

lecturer, good at experiments and practical work, and possessed the gift—unfortunately so rare in those who hold such appointments—of inspiring his students with enthusiasm.

In 1889 he was invited by a well-known financier to act as consulting-mineralogist in connection with some gold-mines in South Africa. After taking due precautions as regards possibilities in the future, in which part of the transactions the Doctor's turn for matters pertaining to law came into useful prominence, he vacated the Chair at St Andrews, and went to South Africa. But after making a full and proper inspection of the evidence on the ground, the Doctor felt himself obliged to express himself unable to endorse some of the statements that had been made regarding the enterprise referred to. This step led to his return to Britain, and to some legal proceedings, in which the Doctor won his case. It may be mentioned that it was from the annuity which his foresight and legal acumen enabled him to secure from this undertaking, before abandoning his professorship at St Andrews, that he drew part of his income in the later years of his life.

Mineralogy formed the chief of Dr Heddle's many pursuits. It was upon this, his favourite science, that nearly all his energy, his time, his thought, and also large sums of money were expended. It is a matter of common knowledge how that, in the course of a long and active life, he acquired one of the finest general collections of minerals ever amassed by any one man, and also how that, during the same time, he diligently explored nearly every mountain and glen, and almost every part of the coast of Scotland, in search of minerals. With Mr Patrick Dudgeon of Cargen, Mr Harvie-Brown of Dunipace, and a few other chosen friends of similar tastes, he visited every locality for minerals which previous observers had recorded, and furthermore, himself added a large number of new localities to the list previously known. These visits resulted in the acquisition of the celebrated "Heddle Collection of Scottish Minerals," the finest local collection in the world. It must be borne in mind that travelling in the Doctor's early days was by no means the comparatively easy

and inexpensive matter that it is now. There were then few or no railways, steam-packets, or coaches; and matters were even worse as regards housing accommodation. It is also a matter of common knowledge how that circumstances led to Dr Heddle and some friends making an arrangement whereby the Doctor's Collection of Scottish Minerals became the property of the nation. They are now located in the Gallery of Scottish Geology and Mineralogy in the Edinburgh Museum of Science and Art, where their arrangement was commenced by Dr Heddle and the writer of this notice, by whom the work is now being carried on.

Dr Heddle wrote a large number of papers, chiefly on mineralogical subjects. The majority of one section of these appeared in the *Mineralogical Magazine*, under the general title of "The Geognosy of Scotland." They include, as the title suggests, contributions to the Geology, as well as to the Mineralogy of the Doctor's native land. Another group of contributions was published in the *Transactions of the Royal Society of Edinburgh*, under the general name of "Chapters on the Mineralogy of Scotland." The Doctor's style was somewhat high-flown and rhetorical; but those who will take the trouble to peruse the above-mentioned papers carefully, will find them full of terse statements, charged with suggestive matter, and embodying many original ideas. Not a few of these appeared before the time when people in general were quite prepared to receive them, and they have consequently (as is usual in such cases) been somewhat extensively appropriated (generally without acknowledgment) by writers whose stock of original ideas has been more limited. For some of these researches the Doctor was awarded the Keith Medal of the Royal Society of Edinburgh in 1878. He brought out a new edition of Greg and Lettsom's "British Mineralogy" in 1858, and he contributed the article "Mineralogy" to the ninth edition of the *Encyclopædia Britannica*. He surveyed and published a map of the Geology of Sutherland—as difficult a piece of work as it was possible for any one man to undertake.

He was one of the founders of the Mineralogical Society

of Great Britain and Ireland, and was one of their earliest presidents. He was also at one time President of the Geological Society of Edinburgh, and while holding that office was chiefly instrumental in urging upon the Government of the day the importance of instituting a Geological Survey of Scotland. He was one of the oldest members of the Royal Physical Society, and took an interest in its welfare to the end of his life.

Reference has already been made elsewhere to the fact also that, for many years, Dr Heddle had been engaged on a comprehensive work on the "Mineralogy of Scotland," of which the greater part of the manuscript was completed by the Doctor himself, and of which the illustrations, consisting chiefly of most beautiful and delicately-drawn restorations and diagrams of crystals of Scottish minerals, to the number of over six hundred, were also nearly all completed by the Doctor himself. This work is being edited and completed by Dr Heddle's old friend, Mr Alexander Thoms, and the writer of this notice, and it is hoped that the work may be issued to the public within a comparatively short time from the present date.

Regarding Dr Heddle's personal characteristics, one or two other points call for remark. Allusion has already been made to the Doctor's strong dramatic instincts and to his histrionic talents, to his fondness for receiving mental impression of things grand, mysterious, and vast, as well as to his equally marked fondness for impressing others with conceptions of the same kind. There must be very few of Dr Heddle's acquaintances who have not been made aware of this characteristic of his. It was his power of mimicry, strong sense of the ludicrous, powerful dramatic instincts, and fondness for impressing those around him, which combined to make him one of the grandest story-tellers Scotland has ever known. Give him a few striking facts and a second or two to think over them, and he would found upon these a story which would command the attention and interest of all within hearing. Like Turner with the details of a landscape in his mind, the Doctor would think over and rearrange his facts, adding an artistic touch here, enlarging there, throwing

subordinate facts into the background, and embellishing with minor details here and there throughout, until the whole was grouped into a striking and harmonious word-picture. There was a marvellous verisimilitude about some of the Doctor's stories; so marvellous, in fact, that it occasionally happened that a few shallow-pated listeners accepted the whole story as perfectly true.

But the Doctor was too much of an artist in such matters not to know where and when to introduce some palpable incongruity, or self-evident anachronism, which, to persons of average intelligence, at once marked off the fiction from the fact. I have heard many of the Doctor's stories, and have been as much delighted and amused with them as any one else; but I never hesitated with regard to what he intended I should believe. It is not every man that possesses this faculty of presenting fact in the garb of fiction in such a manner as to make it evident which was meant. It was this same power of embellishing a few bare facts in such a manner as to present them to his fellow-men in the form of an interesting narrative, which formed the chief element of success in the works of such writers as Sir Walter Scott, Defoe, and others; and it is well known that it is the same faculty, manifested in a different form, which has made one of Dr Heddle's daughters succeed as a writer of fiction.

Another characteristic of the Doctor calls for remark. All of his acquaintances were made fully aware of the fact that, for some few years past, Dr Heddle enjoyed bad health. But so powerful was his interest in his favourite pursuits, that the very mention of them would generally make him forget all his ailments, real and imagined, and he was then able to perform great walking feats, or to climb high mountains, to wield ponderous hammers, or to carry heavy bags of stones, each to an extent which few much younger men could well imitate. The large size of his hammers was very well known to his friends. The Doctor gave me a very big one which had been much used in his past work; and another one, much used in making his Scottish collection, will be placed in the Museum here. Even his alpenstock was bigger

than anyone else's, and I may truly say of it, as was said of the timber carried by one of the giants of old, that "his staff was like a weaver's beam."

Like most other persons of strongly marked character, the Doctor evinced strong likes and dislikes, and therefore occasionally made enemies. But his dislikes to the persons in question were usually founded upon their having violated some principle, and not upon some motive affecting the Doctor himself. I cannot recall a single instance known to me of the contrary. In the case of a small number of persons of whose public conduct the Doctor had more or less reason to disapprove, the very mention of their names, even when he was in a state of extreme bodily and mental prostration, acted upon him like the sound of a trumpet-call to an old war-horse, and then those around him had the greatest difficulty in bringing him back to a state of quiet.

Notwithstanding these little weaknesses, which are common to so large a section of mankind, the Doctor was much admired by those who really knew him. For myself, who had much to do with him, I may say that, taking him all in all, I looked up to Dr Heddle much as Boswell looked up to Johnson. Like his prototype, Dr Heddle did a vast amount of original work of good quality, and in the face of many difficulties; like Dr Johnson he was modest, and never sought honours (so none were conferred on him); like Dr Johnson he never appropriated other men's ideas; and, like Dr Johnson also, he was much given to doing kindly acts, in a quiet way, towards his fellow-men, and looking for no reward. The memory of one of whom we can truly say these things must surely long remain fresh in the minds of men of science.

VII. *The Mammalia and Birds of Franz Josef Land.* By WILLIAM S. BRUCE, F.R.S.G.S., and WILLIAM EAGLE CLARKE, F.L.S.

(Read 16th March 1898.)

I. MAMMALIA, by WILLIAM S. BRUCE, F.R.S.G.S., with Notes by Mr JAMES SIMPSON.

In the beginning of June 1896, while in charge of the Observatory at the summit of Ben Nevis, I was asked by the Secretary of the Jackson-Harmsworth Polar Expedition whether I would join the expedition as naturalist. After eight hours' preparation, exclusive of the time it took me to descend the mountain and to travel to London, I joined Mr Harmworth's yacht, the "Windward," at 10 A.M. on Tuesday, the 9th of June. By 25th July the "Windward" reached Cape Flora, Franz Josef Land, the headquarters of the expedition. On our arrival we found Dr Nansen and Lieutenant Johansen had found their way to the encampment. They returned with the "Windward" to Norway sixteen days later. On the 3rd of September 1897, the whole expedition returned to London. It was during this period that I was enabled to make the observations and collections of the Mammalia and Birds of Franz Josef Land. I placed the collection of birds in the hands of my friend, Mr Eagle Clarke, and he has very ably described the avifauna of Franz Josef Land. The whole paper is an account of all the observations on mammals and birds that have been made in Franz Josef Land by Payer, Leigh Smith, Nansen, and the Jackson-Harmsworth Polar Expedition, and of the collections brought back by them. The chief interest lies in the fact that so few observations and collections have been made in Franz Josef Land, only one expedition previous to Mr Harmsworth's, namely, that of Mr Leigh Smith, in his first voyage of the "Eira," having succeeded in returning to Europe with its ship intact. Previous to my arrival in 1896 there was no zoologist on the expedition. Dr Reginald Koettlitz, however, medical officer and geologist to the expedition, made a number of interesting observations

on the habits and structure of the Polar Bear, besides taking many interesting notes on the birds. The former will form the subject of a separate communication, the latter are embodied in Mr Eagle Clarke's section of this paper. We are both extremely indebted to him for the valuable help he has given us. I have also to thank Mr James Simpson for the two interesting notes he has added to this paper on some bones which I handed him for examination.

1. URSUS MARITIMUS.

The Polar Bear is one of the two land mammals of Franz Josef Land, if indeed it can be so called, for it lives mainly on the floe, and only wanders on to the land occasionally, and seldom far from the water's edge, although I have met with bears' tracks more than two miles from water, crossing a neck of land. Dr Nansen shot nineteen at his winter quarters in 1895-96; the Austrians over sixty; and over one hundred and twenty were seen by the Jackson-Harmsworth Expedition during the three and a half years' sojourn in Franz Josef Land. Dr Koettlitz took measurements of the length of nearly all these bears, and the greatest length was 8 feet 1½ inch from tip of nose to tip of tail. Payer and others have mentioned bears of much greater length, up to even 11 feet, but no bear of such enormous size was seen by our Expedition. Payer gives an illustration of a bear emerging from its snow-cave. Five such caves were found by our Expedition. It is for the female bear, to give her shelter while she is giving birth to her young, and probably sometimes for protection in stormy weather during winter, but in no way a hibernating hole,—bears, both male and female, wandering about all the winter. Each bear is usually found alone, unless it be the case of a mother with cubs. The young are probably born in January or February, and remain at least eighteen months with their mother. Open water is essential to the life of the bear, and if the ice is tight they will prowl about the edge of cracks in the ice, and around seal-holes—seals being their main articles of diet. But they do not altogether depend on seals, for when these fail they will take almost anything they can get.

Grass is frequently found in their stomachs, and it is not unfrequent to find patches of turf scraped up by bears. They will ascend glaciers; I have seen their tracks as high as 250 feet, and on more than one occasion have they been seen and shot high up on the taluses of Franz Josef Land. Dr Koettlitz found that the brains of bears varied considerably in weight, there being a light-brained bear and a heavy-brained bear, and that the skulls presented differences in the prominence of their crests. He also found many cases of broken bones which had become fused together again. Caries of the teeth, cysts, fibrous tumour, exostosis, salivary calculus in the parotid, arthritis deformans or osteo-arthritis were noted by Dr Koettlitz. The liver of bear we found poisonous. Two or three cubs were captured alive, and these were kept alive for a time at Elmwood during the winter of 1894-95; they were sent home by the "Windward" when she broke loose from the ice in 1895, but they died before reaching Britain. The bear is wary and often timid, although if hungry or at bay it becomes bold, and is ready to attack; it may also become bold if one attempts to rob it of its food. It stalks its prey, creeping up to it noiselessly from under cover of crushed-up hummocky ice, as was shown in the case of Lieutenant Johansen, when he was knocked down before either Dr Nansen or the two dogs were aware of the fact. I have been similarly stalked, and had it not been for my companions on shore, who had seen the bear stealthily approaching me, I might, in a few minutes, have felt the weight of its paw.

2. Canis lagopus.

The Fox is the second land mammal of the Franz Josef Land Archipelago. Payer saw many foxes' tracks, and so did our Expedition, but Leigh Smith and Nansen and Johansen had more evidence of their existence. In the case of Nansen they became quite troublesome, stealing from his store of meat. This was not unlikely due to the fact that both Payer and ourselves had a considerable number of dogs. During the fifteen months I was in Franz

Josef Land, I only saw foxes three times, twice at Cape Flora and once at Mabel Island.

? Lepus borealis

Payer mentions having seen the track of a single Hare; but neither Leigh Smith, Nansen, nor ourselves saw any trace of this animal. It seems likely, therefore, that Payer was mistaken in recording this animal, and I think it should scarcely be included in the list of mammals.

3. Rangifer tarandus.

At the end of July 1897, I made an interesting discovery of reindeer horns and bones, on a raised beach some 80 to 100 feet above sea-level, at Cape Flora. These are described by Mr James Simpson. Leigh Smith discovered reindeer horns, and others were found previous to my arrival in Franz Josef Land in 1896. The question is: How these horns and bones of reindeer came to be found in Franz Joseph Land? And I think the most likely suggestion comes from Mr B. N. Peach, F.R.S., who thinks that they may have been carried there by ice-floes from Siberia, and were stranded upon this beach when it was at sea-level. So also, perhaps, to a large extent we can account for the bones of seals, whales, and bears being found on many of the raised beaches.

4. Balæna mysticetus.

There is no doubt that many of the bones of whales found throughout Franz Josef Land on the raised beaches belong to this species. Mr Simpson identifies many as such, and a long blade of baleen, found by Dr Koettlitz, measured 6 feet 6 inches long. On account of its length, this can be no other than the baleen of *Balæna mysticetus*, for it was a weathered piece, and must have been even longer than this originally. Neither Payer, Nansen, nor the Jackson - Harmsworth Expedition saw any signs of any living Bowhead Whale, and there appears to be considerable doubt as to this whale having been seen by Leigh Smith's party.

5. Balænoptera.

I found the bones of this genus on the raised beaches at Cape Flora, Cape Gertrude, and elsewhere. They are described by Mr Simpson on page 86.

6. Beluga leucas.

On two occasions I was fortunate enough to see schools of White Whales quite close. The first time was when the "Windward" was landing stores at Cape Flora, lying outside the land floe, at the end of July 1896. A school of about thirty of these whales came from the direction of Bell Island, and passed to the southwards. The second occasion was at the beginning of June 1897, at the edge of the land floe, 1½ mile to the S.W. of Elmwood. I was attending to some lines I had been setting daily, and was tow-netting, when a school of about thirty of these animals passed me, going in the same direction as in 1896. I also found the bones of this species at Cape Mary Harmsworth.

7. Monodon monoceros.

Narwhals were seen on three or four occasions by the whalers who visited Franz Josef Land for the first time in 1897. Once they were seen off Eira Harbour, and again they were seen in Gray Bay. Neither Payer nor Leigh Smith record them, and they are thus an addition to the mammalian fauna of Franz Josef Land.

8. Phoca fœtida.

I saw the Ringed Seal, or Floe-Rat, frequently in the neighbourhood of Cape Flora, and at other places along the coast. Two at least of these were shot.

9. Phoca grœnlandica.

A Saddle-back Seal was shot by Dr Koettlitz during one of his sledge journeys, previous to my arrival. It was lying by its winter hole in the ice.

10. Phoca barbata.

Quite near to the land we met with Ground Seals, but not in any great numbers.

On an excursion to Bruce Island on the 23rd of May 1897, Dr Koettlitz, Mr Wilton, Mr Heyward, and myself came across five seal-holes near that island, in the floes stretching across Bates Channel. Seals were lying outside these holes. Two of us tried to approach stealthily to see what kind of Seals they were, but while we were yet a long way off, and unable to make out what the species were, they had slipped into the water. I measured one of these holes, it was 15 inches in diameter, through ice that was 4 feet thick, and it was rather irregular in shape, not going quite perpendicularly into the water. Dr Koettlitz and I found another of these holes about midway between Cape Forbes and Bell Island, whilst crossing the Nightingale Sound floe on 24th May 1897. It was similar to the others; we also saw some others in the distance. It is very likely, I think, that most of these were Saddle-back Seals' holes, although some may have belonged to Floe-Rats (*P. fœtida*).

11. Trichechus rosmarus.

Lastly there is the Walrus, which has become a notable animal in the history of Franz Josef Land, since, for the first time, in 1897, commerce tried its fortunes in this part of the Arctic seas, because of the reports of walrus having been seen plentifully by Leigh Smith, Nansen, and ourselves.

Few people would associate this event with the extraordinary development of the bicycle of late years; yet since walrus hide has been found to be the best material obtainable for burnishing parts of these machines, it is natural that the skin of this unfortunate animal should have risen to five or six times the value it was two or three years previously, and it is now worth about £10 in a full-grown animal. One of the Scottish whalers—the "Balæna"—obtained as many as five hundred skins. It is, however, regrettable to note that for every skin obtained two or three other animals must have been lost, for they were shot in the water and sank to the

bottom; thus, this one whaler must have killed at least fifteen hundred to two thousand walruses for the five hundred skins taken on board. How many young perished, having their mothers killed whilst suckling, it is difficult to estimate. But if Franz Josef Land waters are to be hunted for walrus, then the sooner the protective measures are taken by some country the better, or else the walrus will, before long, become an animal of the past.

The walrus has often been described as ungainly and unshapely, and this is true of dead animals and museum specimens; but there is no more magnificent animal when suddenly, with a blast, he throws his enormous head above the water, and, with his small, blood-shot eyes and great white tusks, bids defiance to all as he gives vent to a gruff resounding bark. The bulls are careful of their cows, but it is most striking to see an old cow throwing her flipper round her calf when danger is at hand. I have seen a wounded cow, instead of hurrying away before she should get another bullet, seize hold of her calf in this way, and endeavour to take it away out of reach of harm. Another striking feature of maternal affection in these animals is shown when a calf is left motherless, another cow will take care of that calf. I have seen this on two or three occasions. Very few old bulls were found among the walrus during the summer months at or about Cape Flora, nearly all were females, and most of them in July and August were attended with young. They herded together, and I have seen a closely packed herd of forty or fifty of these females come up to the ship, each with a cub upon its back. I found the usual food in the stomachs of those I examined to be *Priapulus caudatus*, and remains of Lamellibranchs and Gasteropods, an occasional Amphipod, and small stones, but never any shells, the molluscs evidently being shelled before being swallowed.[1]

The following eleven mammals are those which have been seen or captured alive, or whose remains have been found in Franz Josef Land. Of these, perhaps only eight can strictly

[1] Since writing this I have been on another voyage to the Arctic, and have found Lamellibranch shells in the stomachs and intestines of walrus, even down to the rectum.

be said to be indigenous, the reindeer and whales' bones having probably been stranded there in the same way as the drift-wood that is found on nearly all of the raised beaches. In addition to these there is *Lepus borealis,* but I do not include this in the list, as its existence rests on such slender evidence.

1. *Ursus maritimus.* 2. *Canis lagopus.*	Land Mammals.
3. *Rangifer tarandus.* 4. *Balæna mysticetus.*	Probably stranded on raised beaches by drift-ice.
*5. *Balænoptera.*	
6. *Beluga leucas.*	
*7. *Monodon monoceros.*	*Note.*—Species new to the fauna of Franz Josef Land are marked thus *.
*8. *Phoca fœtida.*	
9. *Phoca Grœnlandica.*	
10. *Phoca barbata.*	
11. *Trichechus rosmarus.*	

Note No. 1.—Mr W. S. Bruce has requested me to examine and report on some bones of Cetacea he collected in Franz Josef Land. In the first instance I shall notice those specimens which appear to me to belong to one and the same animal. They are as follows:—A series of six anchylosed cervical, two lumbar and one caudal vertebræ; also the shaft of a humerus with its loose proximal epiphysis. These bones were all found not very far apart, and they present exactly the same weathered appearances. The lumbar and caudal vertebræ are minus their epiphysial plates, so that the animal was not a full-grown adult; besides, the shaft of the humerus, with its loose epiphysial head and the absence of an unanchylosed distal segment, is another proof of the same fact. The length of the shaft of the humerus is 12½ inches, and its circumference round the centre 17⅞ inches, so that the shaft is comparatively long in relation to its girth.

With regard to the species to which these remains belong, it may be noted that the anchylosis of the cervical vertebræ is one of the distinguishing characters of the spinal column of the Right Whale (*Balæna mysticetus*), and, further, that the

humerus referred to belongs to that species I have confirmed by comparison with specimens in the Anatomical Museum of the University; also from these Museum specimens I am of opinion that the humerus under consideration is from an animal about 25 feet long.

In addition to the above remains, I received a dorsal and a lumbar vertebra and two ribs. These I am inclined to refer to the genus *Balœnoptera,* but the paucity of the specimens prevents me from determining the species with certainty, although, from the size of the lumbar vertebra, it might well have come from an animal between 40 and 50 feet long, evidently not adult, as the bodies are without their epiphysial plates.—J. S.

Note No. 2.—On his return from Franz Josef Land, Mr W. S. Bruce, Naturalist to the Jackson-Harmsworth Expedition, presented to the Anatomical Museum of the University of Edinburgh some interesting animal remains which he had found in that country. These consisted of four portions of antlers of the reindeer, along with a tibia of that animal, while the "find" also included the tibia of a seal. The largest deer horn belongs to the left side, is adult, and the distance between the point of attachment to the skull and the root of the brow tine is 1 inch; from the same point to the first bifurcation, 8¼ inches; while the greatest breadth of that portion is 2½ inches. The blades are broken off, and only a small part of the brow tine remains, so that the characters peculiar to the American and the Lapland species cannot be recognised. Other two of the specimens of horns are 8 inches in length, and belong to an adult animal, whilst the fourth may be called the beam of the antler of a young animal. It is 13 inches long, and for nearly a third of its length is cylindrical, with a diameter of half an inch. The proximal end of the tibia is absent, but the shaft and distal end possess all the characters of a reindeer bone. The tibia of the seal is 9½ inches in length, but the absence of other specimens with which to compare it renders it a difficult matter to refer the bone to any particular species.

In connection with the reindeer bones, Mr Bruce says that this animal does not exist in Franz Josef Land.—J. S.

II. BIRDS, by WILLIAM EAGLE CLARKE, F.L.S., with Notes by WILLIAM S. BRUCE, F.R.S.G.S.

On his return from a year's residence in Franz Josef Land, my friend Mr Bruce kindly placed the birds collected by him in my hands for examination and record,—hence this contribution. I am glad to be able to include Mr Bruce's useful and interesting Notes on the Land and its Birds. These appear in brackets, with Mr Bruce's initials.

It has been thought desirable to include in this contribution the names of *all* the species of birds which have been observed, or supposed to have been observed, in Franz Josef Land by the few explorers who have visited this, the most northern of archipelagos, and thus to make it a complete record of our present knowledge of its avifauna.

Certain species in the records, the occurrence of which in Franz Josef Land I consider to be extremely doubtful, are particularised by having a query prefixed to them, and they are also not numbered. A few others in the list may, perhaps, require confirmation, but it is undesirable to exclude them, inasmuch as they are not unlikely to occur.

The materials for a complete account of the avifauna of Franz Josef Land are not voluminous. That this should be so is, no doubt, due to the fact that the archipelago remained undiscovered until the year 1873; and it has, for this and other cogent reasons, been comparatively little visited. Indeed, most of the islands of this extensive group have never been explored, and much remains to be accomplished before our knowledge of the birds, and more especially of their distribution over the isles, can be regarded as anything like complete.

The following works contain all that we know about the ornithology of the Franz Josef Land Archipelago; and to these frequent allusion will be made in this paper:—

1876. PAYER (JULIUS). "New Lands within the Arctic Circle. Narrative of the Discoveries of the Austrian ship 'Tegetthof' in the years 1872-1874." [A translation of "Die österreich-ungarische Nordpolar Expedition in den Jahren 1872-1874." Wien, 1876.]

The Austrians, under Lieut. Payer, explored the eastern portion of the archipelago, from Wilczek Island in 79° 51′ N. lat., by Austria Sound to Cape Fligeley, on the western side of Crown Prince Rudolf Land, in 82° 15′ N. lat.

A mere list of birds "found in the region between Novaya Zemlya and Franz Josef Land" is given in vol. ii. pp. 90, 91; and it is unsatisfactorily remarked that "most of these occurred also on the coasts of Franz Josef Land."

1881. FEILDEN (H. W.). "Some Remarks on the Natural History of Franz Josef Land," *Trans. Norfolk and Norwich Nat. Soc.*, iii. pp. 201-211.

This paper contains an account of the birds observed during Mr Leigh Smith's first voyage in the "Eira" to Franz Josef Land, in the summer of 1880, during which he explored and made many discoveries on the southern coasts of the archipelago.

1882. NEALE (W. H.). "Notes on the Natural History of Franz Josef Land as observed in 1881-1882," *Proc. Zool. Soc.*, 1882, pp. 652-656.

During this second voyage the "Eira" was lost at Northbrook Island, and Mr Leigh Smith and his party wintered at Cape Flora, to which neighbourhood the Notes chiefly relate.

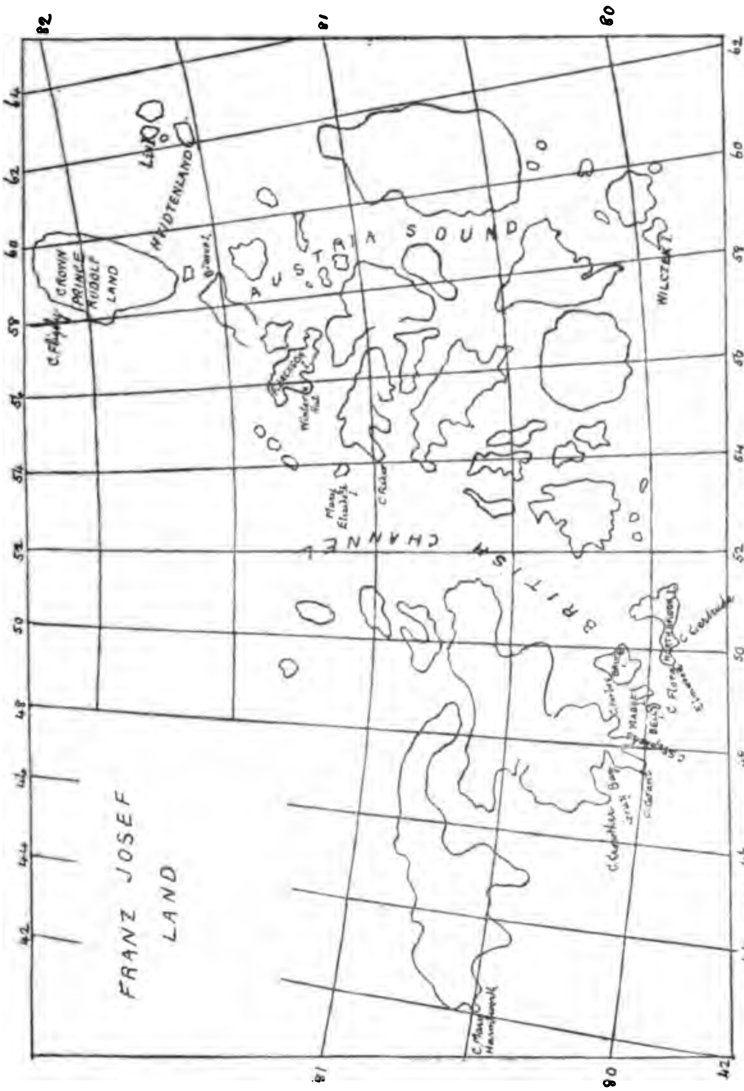
1897. NANSEN (FRIDTJOF). "Farthest North."

Volume ii. contains numerous allusions to the birds seen during the sledge and boat journey from the north-east of the archipelago to Cape Flora.

In addition to the above works, there are two papers by Mr (now Sir) Clements R. Markham in the *Proc. Roy. Geog. Soc.*, vol. iii. p. 129, v. p. 204, also describing Mr Leigh Smith's two voyages, and these papers contain some allusions to the birds observed.

Finally, we have Mr Wm. S. Bruce's collection, made during his sojourn at Cape Flora, while an officer of the Jackson-Harmsworth Polar Expedition. The species obtained or observed during this expedition are nineteen in number, out of a total of twenty-two for the archipelago: their names are marked with an asterisk in the following list. Five of the birds procured are new to the fauna of Franz Josef Land.

Southern Franz Josef Land lies some 200 miles to the east of Spitzbergen, and 270 miles north of Novaya Zemlya.



W. EAGLE CLARKE DEL.

OUTLINE MAP OF FRANZ JOSEF LAND.

At the conclusion of this paper a comparison will be instituted between the bird-life of this region, which is the most northerly—lying, as it does, between 80° and 82° 30′ N. latitude—and that of Novaya Zemlya and Spitzbergen.

[?] LINOTA sp. inc.

Neale, Proc. Zool. Soc., 1882, p. 654.

Dr Neale remarks that he is uncertain about this bird. No specimens were obtained, but some old whaling hands among the crew of the "Eira" called certain birds on the land by this name.

Mr Bruce informs me that he did not see any Linnet-like bird during his residence in Franz Josef Land. The claim of this *Linota* to be included in the avifauna of Franz Josef Land, resting on the evidence it does, must therefore be regarded as unsatisfactory, and requiring confirmation.

Linota holboelli has, however, long been known as an inhabitant of Spitzbergen, and breeds there; but as yet no species of *Linota* has been discovered in Novaya Zemlya. Heuglin (*Ibis*, 1872, p. 65) believes he saw a "*Linaria*" on Waigats. Mr H. J. Pearson, however, saw Linnets on Waigats, and obtained adult *Linota linaria*, with nest and eggs, at Habarova (*Ibis*, 1898, p. 192).

1. *PLECTROPHENAX NIVALIS (Linn.).

Payer, *op. cit.*, ii. p. 91; Feilden, *t. c.*, p. 209; Neale, Proc. Zool. Soc., 1882, pp. 653, 654; Nansen, *op. cit.*, i. p. 308.

Mr Bruce's collection contains adults, young, and a nest of the Snow Bunting, which is quite common as a breeding-bird around Cape Flora.

The Snow Bunting has come under the notice of all the explorers of Franz Josef Land, where it is widely distributed, for Dr Nansen observed the bird at Torup Island, in latitude 81° 30′, in August 1895.

[The Snow Bunting remained plentifully with us in the autumn of 1896 until the 14th of October, and the last was seen on the 30th. Thus this bird was the last species, by eight days, to remain with us. The sun disappeared about the 27th. The first seen in the spring of 1897 was on the

16th of April, and it was the last of the breeding-birds to arrive. About half-a-dozen nests were taken at Cape Flora, and no doubt many more could have been procured if desired. The nests were placed among stones; but one was on an exposed ledge of a rock, about five feet from the ground, and just large enough to hold it; while another was in a deep crevice, and a third under an overhanging piece of turf. We saw the first young birds on the 26th of July 1896, and the 10th of July 1897.

The presence of this bird on Bruce Island is rather striking (it probably breeds there), since the island is almost ice-covered, one or two narrow strips near its edge being the only ground free from ice.—W. S. B.]

2. *CALCARIUS LAPPONICUS (Linn.).

Several fully adult males of the Lapland Bunting were obtained by Mr Jackson at Cape Flora on the 28th of May 1896. These specimens were exhibited at the meeting of the British Ornithologists' Club, on the 17th of November 1897 (*Bull. Brit. Orn. Club,* No. xlviii. p. 14).

This species was an unlooked-for addition to the fauna of Franz Josef Land; for the archipelago lies not only far to the north of the bird's previously ascertained distribution, but its physical conditions are of an order not likely to prove attractive to the species, and to induce it to become a summer visitor. Indeed, we can only regard Mr Jackson's specimens as mere stragglers from Novaya Zemlya, where this bunting is uncommon during the nesting season. It is quite unknown to Spitzbergen.

3. *OTOCORYS ALPESTRIS (Linn.).

A female Shore-Lark, in immature plumage, in Mr Bruce's collection, was shot by Mr Armitage on the 9th of June 1897, near Elmwood, the station at Cape Flora.

This species is new to the avifauna of Franz Josef Land, which is, moreover, the most northerly region in which the bird has yet been observed. It is quite unknown in Spitzbergen, but is not an uncommon summer visitor to Novaya Zemlya. Whether this bird is more than a straggler to

Franz Josef Land remains to be ascertained, but the probability is that it is a mere casual in that inhospitable region.

4. *NYCTEA SCANDIACA (Linn.).

Strix nivea, Payer, *op. cit.*, ii. p. 91.
Nyctea scandiaca, Neale, Proc. Zool. Soc., 1882, pp. 653, 654.

The collection contains an adult female Snowy Owl, which was caught by Mr Wilton, near Cape Flora, on the 26th of August 1896.

This species appears to be not uncommon about Cape Flora; but whether it is a straggler to Franz Josef Land—where Lemmings and Ptarmigan appear to be unknown—or a summer visitor, is at present a matter of conjecture: Mr Bruce inclines to the latter belief.

Dr Neale remarks that it was the first bird to arrive at Cape Flora in the spring of 1882, a Snowy Owl having appeared there on the 8th of February, and again on the 16th and 19th of that month.

[The Owl captured by Mr Wilton must have been ailing, for, as a rule, one cannot get within rifle-shot of these birds. They were frequently seen at Cape Flora in the summer and autumn of 1896, and they preyed upon young birds, chiefly the young Looms. The first for 1897 was seen by Mr Heyward on the 29th of May, and Mr Wilton saw one on the following day.

The nest of this Owl was not found, and it must remain uncertain whether this bird breeds in Franz Josef Land. Very likely it does, but I doubt whether it bred at Cape Flora in 1897.—W. S. B.]

5. FALCO sp. inc.

Falco candicans, Neale, Proc. Zool. Soc., 1882, pp. 653, 654.

Dr Neale refers to the Greenland Falcon, the "Falcon Hawk," seen on the 20th of April 1882, at or near Cape Flora. No species of diurnal bird of prey came under the notice of Mr Bruce and his companions during their sojourn in the archipelago, nor, indeed, has any been recorded by other explorers of Franz Josef Land.

The specific identity of the Falcon that from time to time visits Spitzbergen and Novaya Zemlya[1] has not been satisfactorily determined, but the whiteness of the specimens generally alluded to makes it probable that the Greenland bird is the one that wanders most frequently to these Arctic islands, including, it appears, Franz Josef Land.

6. *Bernicla brenta (Pallas).

Neale, Proc. Zool. Soc., 1882, pp. 653, 654; ?Feilden, *t. c.*, p. 209; Markham, Proc. Roy. Geog. Soc., v. pp. 210, 216; ?Nansen, *op. cit.*, ii. pp. 335, 435, 436.

The Brent appears to be the only species of Goose found in the region, and is no doubt the species alluded to under the name of "Goose" or "Geese" in the writings of Colonel Feilden and Dr Nansen. The former records that traces of a Goose were observed by the members of Mr Leigh Smith's first "Eira" Expedition; and Dr Neale says that during the second expedition made in that vessel, Brent Geese, along with Rain-Geese [Red-throated Divers], were seen and shot on the cliffs, 700 feet above sea-level. He also states that a great many Brents came to the low land, near the pond, at Cape Flora, but that no signs of a nest could be found anywhere.

Dr Nansen found traces of Geese, and a Goose's egg-shell, on Mary Elizabeth Island, on the 1st of June 1896. He also saw two Geese at Cape Fisher two days afterwards. All these localities are in the southern portion of the archipelago.

These birds emigrated from Cape Flora about the 22nd of September 1881. Sir Clements Markham, quoting from Mr Leigh Smith's Journal, mentions that Brent Geese began to arrive at Cape Flora in June 1882, but that a Goose or Duck was seen on the 12th of March of that year.

[Mr Wilton saw the first Brent Geese on the 10th of June 1897, and shot one of the two seen. I also saw a pair on

[1] Heuglin, in *The Ibis*, 1872, p. 61, considered the bird observed by him in Novaya Zemlya to be *F. gyrfalco;* but in his "Reisen nach dem Nordpolarmeer" (1874), iii. p. 83, he treats of the Novaya Zemlya records under "*Falco* sp.?"

the same day. Brent Geese were seen again on the 13th and 14th. Towards the end of July I saw four or five, and Mr Wilton saw others. The West Ponds were their chief resort.—W. S. B.]

7. *SOMATERIA MOLLISSIMA (Linn.).

Payer, *op. cit.*, ii. p. 91; Neale, Proc. Zool. Soc., 1882, pp. 653, 654; Nansen, *op. cit.*, ii. p. 438.

There are two chicks, a few days old, in the collection. These Mr Bruce obtained at Cape Mary Harmsworth, on the 7th of August 1897.

The Eider Duck does not seem to be widely distributed in Franz Josef Land, though it appears to be not uncommon in the south, to which area all our information refers. Dr Nansen only once mentions seeing it—namely, near Cape Fisher, where a flock was observed on the 4th of June 1896. Dr Neale merely includes this bird in his list, and tells us that it departed from Cape Flora in the autumn of 1881, on or about the 22nd of September.

[We saw the Eider Duck on only two occasions near Cape Flora—namely, on the 28th of August 1896, when a single bird was seen; and on the 15th of July 1897, Mr Wilton saw one male and one female.

At Cape Mary Harmsworth, on 7th August 1897, I found an Eider Duck's nest, with two young birds and an egg just on the point of hatching. Later in the day Mr Wilton and I saw many ducks and ducklings round the north end of the tongue of land. We saw five broods with their mothers, and there were many others swimming among the loose ice. Altogether there must have been several hundreds. This was really the only locality for the species found by the expedition in Franz Josef Land, for only two had been seen and secured at Cape Gertrude before my arrival.—W. S. B.]

8. *STREPSILAS INTERPRES (Linn.).

Dr Koettlitz, of the Jackson-Harmsworth Expedition, informs us that on the 27th of May 1896 he saw a Turnstone at Cape Flora—the only one that he observed in Franz Josef Land. This bird is an addition to the avifauna

of the archipelago, to which it is probably a mere straggler, for it is a scarce bird in Novaya Zemlya.

[?] GALLINAGO sp. inc.

Neale, Proc. Zool. Soc., 1882, p. 654.

I have little doubt that the supposed Snipe seen by the old whaling hands of Mr Leigh Smith's second expedition to Franz Josef Land, as mentioned by Dr Neale, was really the Purple Sandpiper—a bird which I know from experience is called by whalers a "Snipe."

It is almost needless to remark that no species of *Gallinago* is at all likely to occur in Franz Josef Land, or elsewhere in the high north; and a Snipe has never been seen either on Spitzbergen or Novaya Zemlya.

9. *TRINGA FUSCICOLLIS, Vieill.

Bull. Brit. Orn. Club, No. li. p. 36.

Mr Bruce's collection contains a skin of a female Bonaparte's Sandpiper, which was shot on the margin of the pond near the beach at Cape Flora, on the 28th of June 1897, by Mr Wilton. The bird was alone, and no other example was observed.

This bird is not only a new and remarkable addition to the ornis of Franz Josef Land, but it is the first authentic example of this American species that has been obtained in Europe elsewhere than the British Isles, for the Icelandic record is not to be regarded as satisfactory.

The occurrence of this Sandpiper in Franz Josef Land, so far away from its accustomed haunts, is very remarkable; but almost equally remarkable is the fact that it should have found its way there in the breeding-season. It has only visited the British shores during the migratory period in the autumn, and its occurrence in Franz Josef Land in summer admits of no satisfactory explanation.

[?] TRINGA CANUTUS, Linn.

Payer, *op. cit.*, ii. p. 91; Feilden, *t. c.*, p. 210.

Lieut. Payer mentions the "Iceland Knot" as one of the birds observed by the Austro-Hungarian Expedition, but

whether in Barents Sea or on the shores of Franz Josef Land is uncertain. Colonel Feilden, however, includes the Knot among the birds observed during Mr Leigh Smith's first "Eira" Expedition, opining that the "Brown Snipe," reported to him as one of the birds seen, was probably *Tringa canutus.* To this conclusion it is difficult, if not impossible, to assent, for reasons to be stated. I have little doubt that the bird observed by the explorers was the Purple Sandpiper—one of the commonest and most generally distributed species to be found on the shores of the Polar Sea, though one that had not then been identified in this region.

On the other hand, the Knot is quite unknown, even as a bird of passage, nay even as a wanderer, to Novaya Zemlya, or other Arctic isles lying to the north of the Continent of Europe, with the exception of a solitary occurrence in Spitzbergen. Thus it is highly improbable that the Knot should find its way to Franz Josef Land, and there can be no hesitation in regarding it as one of those species, the presence of which in the archipelago requires confirmation.

10. *TRINGA STRIATA, Linn.

The Purple Sandpiper is represented in the collection by two young birds, as well as by two eggs, all of which were procured in the immediate neighbourhood of Elmwood (Cape Flora), where, Mr Bruce informs me, this bird was quite common as a nesting species in the summer of 1897.

It is somewhat surprising that this bird, which is one of the commonest, most widely-distributed, and well-known species inhabiting the Northern Regions, should have hitherto remained unnoticed in Franz Josef Land, to whose fauna it is now added for the first time.

I am strongly of opinion, however, that this bird is the "Iceland Knot" of Payer (*op. cit.*, ii. p. 91); the "Brown Snipe" of the first "Eira" Expedition (Feilden, *t. c.*, p. 210); and the "*Gallinago* sp. inc." of Dr Neale's account (*Proc. Zool. Soc.*, 1882, p. 654) of the birds of the second "Eira" Expedition. It is not necessary to say more here in this

connection, for the subject has already been discussed under *Gallinago* sp. inc. and *Tringa canutus.*

The chicks of the Purple Sandpiper obtained by Mr Bruce were captured on the 4th and the 27th of July respectively. The first caught of these little birds appears to be only a day or two old; while the last obtained, though a mere chick, is clad partly in down and partly in sprouting feathers, and already shows the purple gloss on its dorsal plumage, from which this species takes its popular name.

[I saw a number of Purple Sandpipers during July, August, and September 1896; and Mr Wilton saw the first for the year on the 29th of May. On the 5th of June one came on the snow right up to the window-pane at Elmwood. Late in June a nest with eggs was found, and in July I captured two young ones. The first caught was with its parent, which tried to lure me away; the older bird was one of four, also accompanied by the mother.—W. S. B.]

11. Calidris arenaria (Linn.).

Neale, Proc. Zool. Soc., 1882, pp. 653, 654.

Dr Neale includes this species in his list of birds observed during Mr Leigh Smith's second expedition; and he tells us that on the low lands [at Cape Flora] the Snow-Bunting and the Sanderling were seen, but no nests were found.

The Sanderling does not appear to have come under the notice of the other explorers who have visited Franz Josef Land, and its occurrence there is doubtful. It has been recorded for Waigats by Heuglin ("Reisen nach dem Nord-polarmeer," dritter Theil, S. 118), but there is no record of its occurrence in Novaya Zemlya. It occurs in Spitzbergen in small numbers on migration, but does not breed there.

12. *Sterna macrura, Naum.

Payer, *op. cit.*, ii. p. 91; Neale, Proc. Zool. Soc., 1882, p. 654; Nansen, *op. cit.*, ii. p. 295.

Mr Bruce has adults, male and female, of the Arctic Tern, shot at Cape Flora, out of a party of four which appeared there on the 24th of June 1897.

Although this species is undoubtedly a summer visitor to Franz Josef Land, yet there appears to be no information regarding its breeding; nor do we know much concerning it as a bird of the archipelago. Dr Neale merely includes the Arctic Tern in his list of birds observed in the south during Mr Leigh Smith's second visit, but without remark. Dr Nansen only once mentions this bird in his diary, namely, on the 8th of August 1895, when two "Terns" were seen off the Isles of Hvidtenland. The Arctic Tern in all probability nests in Franz Josef Land, but it has not yet been found breeding by any of the explorers of the archipelago.

[On the 6th of August 1896, I saw a pair of Terns at the end of Windy Gully, Cape Flora; and on the 24th of June 1897, I saw two pairs of Arctic Terns at the west end of Cape Flora. Mr Jackson shot a pair of these later in the day, a male and a female. These were the only occasions on which I saw Terns in Franz Josef Land. I saw a pair when off the east of Spitzbergen.—W. S. B.]

13. RHODOSTETHIA ROSEA, Macgil.

Payer, *op. cit.*, i. p. 285, ii. p. 91; Nansen, *op. cit.*, ii. pp. 270, 272, 282, 283, 295, 297, 298.

When the Austrian explorers in the "Tegetthof" were drifting in the ice south of Franz Josef Land, in the latter part of the summer of 1873, they were fortunate enough to obtain a specimen of the rare Ross's Gull. This fact led ornithologists to surmise that in these new Arctic lands might be found, perhaps, one of the long-sought breeding-haunts of this interesting bird.

The experience of Dr Nansen and his companion Lieut. Johansen in north-eastern Franz Josef Land during the summer of 1895 practically demonstrates that this Gull breeds in considerable numbers in that portion of the archipelago. During their long and arduous sledge-journey over the polar ice, they first observed this bird when approaching Franz Josef Land from the north-east. The first example, an adult, was seen on the 14th of July. After

that date one or two were occasionally observed; and on the 31st four came under notice. On the 1st of August Dr Nansen writes in his diary (p. 283): "It would seem as if the Ross's Gulls kept to the land here; we see them almost daily." When nearing the small group of islands, to which the name of Hvidtenland has been given, numbers of these birds were seen, and Dr Nansen remarks (p. 297): "Yesterday [the 9th of August] we saw a number of them; they are quite as common here as any other species of Gull." On the following day, when off Liv Island, one of the group, he says (p. 298): "We could see a strip of bare land along the shore on the north-west side. Was it there, perhaps, the Ross's Gulls congregated, and had their breeding-grounds?"

[On the 5th of July 1897, Mr Jackson declared he had seen Ross's Rosy Gull. He noted the bird flying high up along with some Kittiwakes, and said that it flew into the cliff, at the back of Elmwood, along with them. My opinion is that it was probably a Kittiwake, and I think this bird should *not* be included in the list of birds seen or captured by the Jackson-Harmsworth Expedition. Only one of us saw the bird besides Mr Jackson, and that individual had a good pair of binoculars, which he directed upon the bird. He neither noticed any rosy colour nor the wedge-shaped tail, both of which are distinctive characters.—W. S. B.]

[?] LARUS ARGENTATUS, Gmel.

Nansen, *op. cit.*, ii. pp. 206, 230, 235.

Dr Nansen, when approaching Franz Josef Land over the ice in June 1895, alludes on three occasions to seeing Gulls, which were "probably Herring-Gulls (*Larus argentatus*)."

The Doctor's surmise was undoubtedly an erroneous one; for the probability of seeing this species beyond the 82nd parallel of N. latitude is not at all likely. Doubtless the birds seen were Glaucous Gulls.

The Herring-Gull is quite unknown to both Spitzbergen and to Novaya Zemlya, and does not occur farther north than the Arctic coast of the European Continent.

14. *LARUS GLAUCUS, Fabricius.

Payer, *op. cit.*, ii. p. 90; Feilden, *t. c.*, p. 209; Neale, Proc. Zool. Soc., 1882, pp. 652, 653; Nansen, *op. cit.*, ii. pp. 326, 331, 349, 414.

The Glaucous Gull has been observed by all those who have visited Franz Josef Land, where it seems to be widely distributed.

Dr Neale found it breeding at Bell Island and at Cape Flora.

Dr Nansen observed it at Frederick Jackson Island in the spring of 1896; and probably the birds seen by him in the north-eastern portion of the archipelago, and regarded as Herring-Gulls, were of this species. He has recently informed us that the surprising statement (*op. cit.*, ii. p. 308) that on the 4th of August 1895, "on the north side of the island [Torup Island] we found a breeding-place of numbers of Black-backed Gulls" was due to an error of his translator. The birds were Glaucous Gulls.

Dr Neale tells us that these Gulls remained at Cape Flora in the autumn of 1881 until the end of October. Sir Clements Markham (*Proc. Roy. Geog. Soc.*, v. p. 216), quoting from Mr Leigh Smith's diary, notes their return on the 5th of March 1882.

[The Glaucous Gull is quite a common bird in Franz Josef Land: both the eggs and young were taken by us. —W. S. B.]

15. *PAGOPHILA EBURNEA (Phipps).

Payer, *op. cit.*, ii. p. 90; Feilden, *t. c.*, p. 210; Neale, Proc. Zool. Soc., 1882, pp. 652, 653; Nansen, *op. cit.*, ii. pp. 284, 295, 304, 326, 414.

Three chicks and an addled egg of the Ivory Gull are in Mr Bruce's collection. These specimens were obtained on the low-lying ground at Cape Mary Harmsworth on the 7th of August 1897. One of the chicks obtained is only a few days old, and the other two, though older, are still in the downy stage. The feet and bills of these young birds strike one as being much coarser and larger than those of other Gulls of the same age.

Dr Neale mentions Cape Flora as a nesting-place, but

Mr Bruce tells me that, though seen constantly and in some numbers, the Ivory Gull does not breed there; the only nesting-station known to him being at Cape Mary Harmsworth. Other nesting-places mentioned by Dr Neale are at Cape Stephen, Bell Island, and Gray Bay; and, according to Mr Leigh Smith, it breeds at May Island, placing its nest on the top of a low basaltic cliff (*Proc. Roy. Geog. Soc.*, iii. p. 131).

Dr Nansen observed this Gull amid the polar ice far to the north-east of Franz Josef Land on the 2nd of June 1895, when, he tells us, he shot two for food. These birds were afterwards not unfrequently seen by him when he was skirting the land; and in August they were found, along with other birds, at the Isles of Hvidtenland.

Dr Neale records that in the autumn of 1881 the Ivory Gulls departed from Cape Flora at the end of October, and arrived there the following spring on the 20th of April. Dr Nansen observed them for the first time in 1896 as early as the 12th of March, at his winter-quarters on Frederick Jackson Island.

[This bird was quite abundant in the autumn of 1896 at Cape Flora, and the last entry in my diary for this species was on the 3rd of October, when about twenty Ivory Gulls and several young ones were observed. In the spring of 1897 this bird was first seen on the 10th of April, when twenty at least were observed in the evening. I do not think that this bird breeds at Cape Flora, and my only experience with the bird as a breeding species is contained in the following account:—

August 7th. To-day we landed at Cape Mary Harmsworth, and the first thing we noted was an immense number of Ivory Gulls, and from their demonstrations and shriekings it soon became evident that they were nesting. As we travelled across the low-lying spit we found this was so. Here there are five or six square miles, or more, of fairly level ground, more or less terraced, being evidently a series of raised beaches. This, if not the largest, is one of the largest areas of bare ground in Franz Josef Land. Beyond a few lichens and occasional patches of moss, there is very

little vegetation, only two flowering plants being found—a saxifrage and a grass, and these very sparingly indeed. There is very little actual soil, and the surface is rough and rugged with large stones. Scattered all over it are numerous fresh-water ponds, the largest of them perhaps two hundred yards across. The first signs of the Ivory Gulls, nests were patches of old moss every here and there, which at first we could not make out. As we advanced we saw more of these patches, and these seemed more compact. On approaching closer to these, the birds made still more vehement demonstrations, swooping down upon us, and giving vent to their feelings by uttering a perfectly deafening shriek close to our heads. Once in the midst of their nests —for these patches of moss were their nests—we had many hundreds of birds around us, first one swooping down to within a foot of our heads, and immediately after another. In some cases they actually touched us, and in one instance knocked the hat off a man's head. Most of the nests were empty, owing to the late date; but here and there was a single egg, and in two nests I found two eggs. Going on through this gullery, we found that near certain nests, which were apparently empty, the birds made even more violent demonstrations than before, and in looking carefully about, we descried a young Ivory Gull in its greyish-white downy plumage, and hardly visible against the stones, which were of a very similar colour. Even the older ones, which were more whitish, were difficult to see among the stones. These young birds would sit crouched in between two or three large stones, and one might at first sight take them for stones also. On picking up a young bird the parents became quite distracted, and threatened us more vehemently than ever. By and by we passed out of this gullery, but farther along we could see others, each with many hundreds of these birds, and we advanced towards them. The gullery we left gradually became quiet; but the birds in the one which we were approaching were beginning to demonstrate in the same way as those at the last. The cries became louder and louder, and in a few minutes we were again in the midst of the deafening shrieks of a host of

terrified yet defiant birds. Again they swooped down upon us, and it seemed quite likely that at any moment they might dash into our faces. So we passed on from gullery to gullery among many thousands of these birds. It was a magnificent sight; the sun was shining brightly in a blue sky, the air was clear, and these handsome birds in their pure white plumage, added brilliancy to the scene. Each nest is, as I have said, composed of a pile of moss, in shape a truncated cone, and may be from 6 to 9 inches in height and from 18 inches to 2 feet in diameter. There is no hollow on the top of this more or less level pile, upon which the egg is deposited, or the young bird sits. I noticed many dead young birds, some quite recently deceased, for they were still warm, while others had been dead for some time; in nearly every case their crania had been indented. Eight young birds were taken on board alive: seven of these reached the Thames on September 3rd, 1897, but next day six of these were dead, and the remaining one found its way to the Zoological Society's Gardens at Regent's Park.—W. S. B.]

16. *RISSA TRIDACTYLA (Linn.).

Payer, *op. cit.*, ii. p. 90; Neale, Proc. Zool. Soc., 1882, pp. 653, 654; Nansen, *op. cit.*, ii. pp 295, 350, 438.

Mr Bruce's representatives of the Kittiwake consist of two chicks, taken on the 20th of July 1897, and a half-grown bird taken a week or two later—all from nests at Cape Flora.

This bird is at least widely, if not generally, distributed in Franz Josef Land. Dr Neale records it as breeding in numbers in the south, at Cape Flora, in the summer of 1882; and Dr Nansen observed it in the north-east, at the Isles of Hvidtenland, on the 8th of August 1895. According to Dr Neale, the Kittiwakes departed from Cape Flora, in the autumn of 1881, about the 22nd of September, and returned the following spring on the 6th of May.

[I noted the last Kittiwakes seen in the autumn of 1896 for the 5th of October, when they came under the notice of Mr Wilton. The first was observed in the spring of 1897 on the 14th of April, and several were seen by Dr Koettlitz on

the following day. On the 24th they were observed returning from the westward. On the 25th there were plenty of them on the cliffs at Cape Flora. On the 19th of May the whole group of Kittiwakes — some five hundred or six hundred—were sitting on the floes in the West Bay. I went to the top of the talus on the 1st of July, with Mr Jackson, in search of eggs, and got, among others, fifty eggs of the Kittiwake and Loom. The Kittiwakes were nesting among the Looms on the ledges, and their roughly-made nests of grasses and mosses contained two eggs each. The eggs proved to be considerably incubated, as did also those of the Loom obtained at the same time.

The Kittiwakes are here the victims of the Skuas and Snowy Owls. The latter especially attack the young birds, while the Skuas rob the old ones of their food.

On the 16th of August the young Kittiwakes were not old enough to fly, and the crew of the "Windward" captured several on the rocks. On the 28th of August 1896, the young Kittiwakes were already leaving their nests. I labelled several of these, in case they should be captured elsewhere.—W. S. B.]

17. *STERCORARIUS CREPIDATUS (Gmel.).

Long-tailed Robber-Gull, Payer, *op. cit.*, ii. p. 90.
Lestris, Feilden, *t. c.*, p. 209.
Lestris sp. incog., Neale, Proc. Zool. Soc., 1882, p. 654.
Stercorarius crepidatus and "Skuas," Nansen, *op. cit.*, ii. pp. 326, 350, 414.

There is, perhaps, some little doubt as to whether all the Skuas that have been observed by the various explorers of Franz Josef Land should be assigned to one species, namely, the Arctic or Richardson's Skua. Mr Bruce considers that the Skua which nests at Cape Flora belongs to this species; and Dr Nansen tells us that the species seen by him was *Stercorarius crepidatus*. The other writers named in the bibliography given above were in doubt as to the identity of the species which came under their notice.

As yet we know little about this Skua and its distribution in the archipelago. At Cape Flora, in the south, it nests in some numbers on the low lands near the shore. In the north-

east Dr Nansen observed this bird in the summer of 1895, and in the autumn at Frederick Jackson Island, where it was busily engaged chasing the Kittiwakes. He also saw it at the same island in the spring of 1896.

[On the 15th of April 1897, Mr Wilton saw the first Skua. It is not uninteresting to note that it was only on the day before, and on this day, that the Kittiwakes arrived.

Several pairs of Arctic Skuas were nesting about Cape Flora. We found the first nest, containing eggs, on the 27th of June, and on the 3rd of July another was found with eggs. The birds played antics when their nests were approached, pretending to be maimed in some way, and trying to lure one after them. The Skuas also swooped down upon our dogs when they were near the nests.

I saw the Pomatorhine Skua (*Stercorarius pomatorhinus*) on the voyage out and home, but not actually on Franz Josef Land, though we shot it before we were out of the ice. —W. S. B.]

18. *URIA MANDTI, Licht.

Uria mandti and *Grylle columba*, Payer, *op. cit.*, ii. p. 91.
Uria grylle, Feilden, *t. c.*, p. 209; Neale, Proc. Zool. Soc., 1882, pp. 652, 653; Nansen, *op. cit.*, ii. pp. 199, 410.

Mr Bruce brought back with him a number of specimens of this Black Guillemot, or Dovekie, in both adult and first plumages. This bird bred, Mr Bruce tells me, in some numbers at Cape Flora, along with the still more numerous Little Auk.

According to Dr Neale, a considerable number of Dovekies breed at the head of Gray Bay, and a good number at Cape Stephen, at Bell Island, and at Cape Flora. The bird came under Dr Nansen's notice at the end of May 1895, on the ice far to the north-east of Franz Josef Land; but he does not again allude to it until the spring of 1896, when he (p. 410) mentions its arrival on the 10th of March, and alludes to its movements from the land to the sea at certain times of the day, in company with the Little Auk. Dr Neale states that the Black Guillemot departed from Cape Flora during the first week of September 1881, and returned to its old haunts on the 18th of February 1882.

[On the 22nd of October several Dovekies were seen, and two of them shot by Mr Armitage; these were the last of their kind seen in the autumn of 1896. On the 4th of March 1897, Mr Wilton saw the first Dovekie of the season. On the 17th the bird was seen in numbers at the Windy Gully Rocks.

The note of the Dovekie while flying is extremely delicate and beautiful—a kind of soft chirping. It is very distinctive, and one could easily tell whether the birds were about without seeing them.

The Windy Gully Rocks form a breeding-place of the Dovekies, and there they are dispersed among their more numerous friends, the Rotges. This species was much less abundant than the Loom.—W. S. B.]

19. *URIA BRUENNICHI (E. Sabine).

Uria arra, Payer, *op. cit.*, ii. p. 91.
Alca arra, Feilden, *t. c.*, p. 209.
Uria bruennichi, Neale, Proc. Zool. Soc., 1882, pp. 652, 653; Nansen, *op. cit.*, ii. p. 244.

In the collection are three adults in summer plumage, two obtained on the 13th of April 1896 and one on the 27th of April 1897; three young in down, taken on the 11th and 24th of August 1894; and a chick on the 27th of July 1897—all from Cape Flora.

Though common enough in the south, there is no information regarding the bird elsewhere in Franz Josef Land.

Dr Neale mentions that there are large "loomeries" at Cape Crowther, Cape Grant, Cape Stephen, Bell Island, and Cape Flora, and that a few breed at Cape Forbes. He found eggs, laid on the bare rock, on the 26th of June 1882. From the "loomery" at Cape Flora 1660 of these Guillemots were shot in September 1881 by Mr Leigh Smith's party for winter stores. Dr Neale notes that it became very scarce at Cape Flora after the 10th of September 1881. It arrived there, according to the same authority, on the 9th of March in the spring of 1882.

Dr Nansen only once mentions Brünnich's Guillemot, namely, on the 16th of June 1895, when he shot a single

bird some way to the north-east of the archipelago, in lat. 82° 19′ N.

[The Looms began to come down from the cliffs at Cape Flora on the 13th of August 1896, and the descent lasted until August 24th. Several old birds came down with one young one; indeed, I have seen as many as five accompanying it. It is a bold flight to take, for the cliffs where they are cradled are from 600 to 800 feet above sea-level, and these young birds are not able to sustain their own weight during so long an essay, but gradually come lower and lower until they strike with a heavy thud on the floe or land. Some quickly recover themselves and hurry away as fast as they can to the open water, while others are harried by the Burgomasters (*Larus glaucus*); and those that are killed afford food for the bears. Many of the young seem to perish, but perhaps this is due to the large number of old ones that had recently been shot for food, namely, over 1400 for winter stores.

On the 25th of August I captured, labelled, and set free nineteen young Looms, but have not yet heard that any of them have been captured. The temperature of a young Loom taken on the 14th of August 1896 was found to be 107°·1 F. Of twenty-three Looms taken during August, seven had fish-bones in their stomachs, while sixteen had nothing.

In 1897 the first Loom was seen on the 20th of March. On the 7th of May, during an excursion to Mabel Island, many Looms and Rotges were seen on the cliffs. There were many Looms making a great noise on the rocks at Cape Flora on the same date, and on the 16th they were in full force on their breeding-ledges in the morning, but in the afternoon there were few, and at night the clouds were down to 300 feet, and all appeared to have left. This visiting and leaving the cliffs continued throughout May and part of June. On the 1st of July I went up the talus (600 feet) and secured about fifty eggs. Some of the eggs were resting in very wet places, but this the bird did not seem to mind so long as it could get a place on a ledge of these densely crowded rocks. There were thousands upon thousands of Looms nesting on cliffs at the back of Elmwood,

our station at Cape Flora, the whole place being alive with them.—W. S. B.]

20. *MERGULUS ALLE (Linn.).

Payer, *op. cit.*, ii. p. 91; Feilden, *t. c.*, p. 109; Neale, Proc. Zool. Soc., 1882, pp. 652, 653; Nansen, *op. cit.*, ii. pp. 308, 312, 320, 351, 403, 404, 410, 414, 438.

The collection contains four Little Auks from Cape Flora, three of which were obtained on the 11th of April 1895, and one on the 27th of April 1897.

This is one of the commonest birds inhabiting Franz Josef Land, where it is widely distributed. Dr Neale found it breeding in great numbers in the south on the lofty cliffs at Gray Bay, also many at Cape Forbes; and Sir Clements Markham (*Proc. Roy. Geog. Soc.*, iii. p. 133) mentions a rookery at Bruce Island.

Dr Nansen observed it to the north-east of Franz Josef Land, in lat. 82° N., on the 10th of June 1895, and on the 26th of June many were seen in the same latitude. At the Isles of Hvidtenland, on the 8th of August, a number of Little Auks were noted; and at Torup Island, on the 17th, there were "myriads." On the 10th of March 1896, at his winter-quarters on Frederick Jackson Island, Dr Nansen mentions that "millions" were seen flying up the sound at 6 A.M., and "when we went out at two in the afternoon there was an unceasing passage of flock after flock out to sea, and this continued until late in the afternoon." It was also observed (p. 410) that this species and the Black Guillemot invariably set forth from the land at certain times of the day towards the open sea, returning in broken lines to their nest-rocks again. At the basaltic cliffs of Cape Fisher, on the 3rd of June 1896, he found these birds breeding in swarms.

Dr Neale tells us that the Little Auk departed from Cape Flora in the autumn of 1881, during the first week of September, and was first observed there in the spring of 1882 on the 2nd of March. It arrived at Frederick Jackson Island in 1896 on the 25th of February, as related by Dr Nansen.

[The Rotges appear to have left Cape Flora about the 14th of September in the autumn of 1896, and they returned on the 9th of March 1897, for on that day I noticed their brilliantly red droppings in the snow: this was the first sign that the Rotges had returned, but we did not see them on that day. On the 17th of March they were in plenty at the Gully Rocks, and, as far as could be seen, they were all in full summer plumage. There were also many of these birds observed on Windward and Mabel Islands during the month. Like the Looms, the Rotges continually occupied and deserted their breeding-cliffs during April, May, and early June. After the 10th of June the Little Auks were seen on the rocks every day during our stay. They bred in the cliffs, at both east and west ends, at Cape Flora in great numbers, though most plentifully in the Gully Rocks. Dr Koettlitz and I saw a good many in the cliffs at Cape Forbes on the 24th of May.—W. S. B.]

[?] FRATERCULA ARCTICA (Linn.).

Lieut. Payer (*op. cit.*, ii. p. 91) mentions the "Lumme" (*Mormon arcticus*) as one of the birds "found in the region between Novaya Zemlya and Franz Josef Land . . . most of these occurred also on the coasts of Franz Josef Land."

It is not probable that this bird was one of the species observed on the coasts of this northern archipelago. It has not come under the notice of any of the explorers who have since visited Franz Josef Land; and it is, moreover, a somewhat uncommon species on the west coast of Novaya Zemlya, which seems to be the extreme limit of the Puffin's eastern distribution in the European Polar area. It is, however, a fairly common species in Western Spitzbergen.

21. *COLYMBUS SEPTENTRIONALIS, Linn.

Neale, Proc. Zool. Soc., 1882, pp. 653, 654.

The Red-throated Diver had hitherto only come under the notice of Dr Neale, among all the explorers of Franz Josef

Land. Rain-Geese (*Colymbus septentrionalis*), he tells us, were seen and shot on the cliffs 700 feet above sea-level, presumably at Cape Flora, but no nests were seen.

It is somewhat strange that such a conspicuous, well-known, and characteristic circumpolar species should have escaped the notice of the other visitors to the same place and to other parts of the archipelago. Dr Koettlitz, however, informs us that three adults and a young bird were seen and shot at Bell and Mabel Islands, on the 11th of August 1895. These were the only Red-throated Divers seen by the Jackson-Harmsworth Expedition in Franz Josef Land.

22. *FULMARUS GLACIALIS (Linn.).

Procellaria glacialis, Payer, *op. cit.*, ii. p. 91; Neale, Proc. Zool. Soc., 1888, p. 653; Nansen, *op. cit.*, ii. pp. 244, 295, 349, 414, 437.

The Fulmar Petrel seems to be widely distributed, and probably breeds locally over a wide area in the region.

Dr Nansen observed it on the 16th of June 1895 when approaching Franz Josef Land, over the ice, from the north-east, and again early in August at the Isles of Hvidtenland, and later still on Frederick Jackson Island in September. On the 3rd of June 1896, he found it breeding at Cape Fisher (p. 437).

Dr Neale only alludes to the "Molly" as a migratory bird, which remained at Cape Flora so late as the 28th of October 1881, and returned in the following spring on the 24th of April; and tells us nothing further concerning it.

[Mr Wilton saw the last Molly on the 6th of October 1896. The first seen in 1897 was on the 7th of April. On May 5th we found these birds breeding at the east end of Mabel Island in abundance, on the basaltic crags. They were then making a peculiar Duck-like sound, quacking in quick succession. Mollies were also seen at Cape Forbes by Dr Koettlitz and myself, and probably breed there.—W. S. B.]

The subjoined tabulation affords, in a condensed form, a

comparison between the ornis of Spitzbergen and Novaya Zemlya and that of Franz Josef Land:—

Orders.	Spitzbergen.	Novaya Zemlya.	Franz Josef Land.
	Species.	Species.	Species.
Passeres,	2	6	3
Striges,	1	1	1
Accipitres,	1	2	1
Anseres,	6	10	2
Gallinæ,	1	None	None
Limicolæ,	7	8	4
Gaviæ,	9	8	6
Pygopodes,	5	7	4
Tubinares,	1	1	1
Totals,	33	43	22

It only remains to remark, that of the twenty-two species which form the avifauna of Franz Josef Land, only ten have been found breeding (though several more—probably five—undoubtedly nest there), and that several of the birds in the grand total are mere stragglers. Six species have been recorded for the archipelago, the occurrence of which is extremely doubtful; but these have been excluded from our calculations, for reasons already stated under the particular species.

We have received from Dr Koettlitz, the geologist to the Jackson-Harmsworth Expedition, a communication containing much useful data concerning the arrival and departure of the various birds prior to Mr Bruce's advent in Franz Joseph Land. These are given below. We desire to express our acknowledgments to Dr Koettlitz for his valuable and much-appreciated contribution.

Dates of Arrival.

	1895.	1896.
Mergulus alle,	Feb. 25.	Feb. 27.
Uria mandti,	,, 25.	,, 24.
Uria bruennichi,	April 4.	Mar. 26.
Pagophila eburnea,	,, 16.	April 6.

DATES OF ARRIVAL (*Continued*).

	1895.	1896.
Fulmarus glacialis, . . .	April 21.	April 8.
Larus glaucus, . . .	May 6.	,, 4.
Plectrophenax nivalis, . .	April 20.	,, 22.
Rissa tridactyla, . . .	June 7.	,, 26.
Tringa [? *striata*], . . .	,, 13.	May 30.
Bernicla brenta, . . .	,, 13.	June 2.
Stercorarius crepidatus, . .	,, 17.	,, 12.
Sterna macrura, . . .	,, 17.	,, 18.
Somateria mollissima, . .	,, 24.	May 28.
Strepsilas interpres, . .	...	,, 27.
Calcarius lapponicus, . .	...	,, 28.
Nyctea scandiaca, . . .	...	,, 26.

DATES OF DEPARTURE.

	1895.
Colymbus septentrionalis, ...	Aug. 11.
Stercorarius crepidatus and young, . . .	Sept. 4.
Uria bruennichi, ...	,, 14.
Sterna macrura, ...	,, 17.
Fulmarus glacialis, ...	,, 18.
Tringa [? *striata*], ...	,, 17.
Larus glaucus, ...	,, 25.
Rissa tridactyla, ...	,, 25.
Plectrophenax nivalis, ...	,, 30.
Pagophila eburnea (adult), ...	,, 18.
,, ,, (young), ...	,, 30.
Uria bruennichi (1 young), ...	,, 30.
Bernicla brenta, ...	Oct. 1.
Mergulus alle, ...	,, 1.
Uria mandti, ...	,, 1.

VIII. *On Some New Myriapods from the Palæozoic Rocks of Scotland.* By B. N. Peach, A.R.S.M., F.R.S., of the Geological Survey of Scotland. [Plate IV.]

(By permission of the Director-General of the Geological Survey.)

PART I.

(Read 16th February 1898.)

At the January meeting of this Society in 1882, I laid before you the results of my investigation of some Arthropod remains from the Lower Old Red Sandstone of Forfarshire, which had up to that time been considered to belong to Isopod Crustaceans, but which proved to be the remains of Chilognathous Myriapods, belonging to two genera. One of these had already been named *Kampecaris* by Page, while to the other I gave the name of *Archidesmus.* Since then, Scudder, the authority on Fossil Insects, has raised these to family rank under the name of Archidesmidæ, which family falls into his order of Archipolypoda, comprising all the Palæozoic Myriapods, with the exception of some anomalous creatures covered with bundles of peculiar spine-like hairs, and a few forms from the Devonian rocks of St John, New Brunswick, which are considered by G. F. Matthew to belong to the great division of the Myriapods, the Chilopoda.[1]

At the time of the reading of my paper, these Myriapods were the oldest air-breathers that had then been described. Shortly afterwards, in 1884, Lindström announced the discovery of a scorpion, *Palæophonus nuncius,* from the Upper Silurian rocks of Gothland, which was afterwards described by Thorell and him.[2] About the same time I gave a short description of another specimen belonging to this species (*Palæophonus caledonicus*) which was brought to me by the late Dr Hunter-Selkirk of Carluke, and which had been found in the Upper Silurian rocks of the Lesmahagow inlier about a year previously.[3]

[1] G. F. Matthew, "On the Organic Remains of the Little River Group," *Trans. Roy. Soc. Canada,* sec. iv. pp. 101-111, pl. i., 1894.

[2] T. Thorell and G. Lindström, "On a Silurian Scorpion from Gothland," *K. Svenska Vetensk. Akad. Handlingar,* 1885, Bd. 21, No. 9 (with one plate).

[3] *Nature,* vol. 31, p. 295, 1884.

In 1885 Whitfield described another Upper Silurian Scorpion, *Proscorpius Osborni*, from Waterville, near New York.[1] At the same time as the announcement of the find of the Gothland and Scottish Scorpions (1884), the discovery of the remains of the wing of a Cockroach from the Middle Silurian rocks of Calvados was announced in France. This was described under the name of *Palæoblattina Duvillei*, Brongniart; but there seems to be some doubt about the exact nature of the specimen. If the determination be correct, this has the honour of being the oldest described air-breather.[2]

While following up a discovery made by the Geological Survey in 1896, of fish remains in the passage beds between the Silurian and Old Red Sandstone rocks of Lesmahagow, Messrs Macconochie and Tait, Fossil Collectors to the Geological Survey of Scotland, last year (1897) found a fragment of a Myriápod in the Upper Silurian rocks of that district, at the same locality, and in the same beds as those from which the above-mentioned specimen of Scorpion, *Palæophonus caledonicus*, was obtained. This discovery throws back the history of the Myriapoda, so that they now seem to rival the Arachnida in antiquity.

The primary object of this part of my paper is to describe the remains of a finely preserved Myriapod from the Lower Carboniferous rocks of East Kilbride, now in the Museum of Science and Art, Edinburgh. The history of the discovery of this specimen is as follows:—About ten years ago, the late Mr Coutts brought me some remains, which he took to be those of Schizopod Crustaceans, and which the late Mr Patton, the indefatigable collector of the fossils of the "Hosies Limestone" of East Kilbride, had obtained from that seam. Among these I found the remains of a Myriapod, which, after being developed, proved to be the head and nine body-rings, in fine preservation, of a new form belonging

[1] R. P. Whitfield, "An American Scorpion," *Science*, vol. vi. p. 87, 1885.

[2] Since the reading of the present paper, Professor Malcolm Lawrie has described before the Royal Society of Edinburgh the remains of a third species of *Palæophonus*, from the Wenlock rocks of the Pentland Hills, which he found in the Hardie Collection, in the Museum of Science and Art, Edinburgh.

to Scudder's family of the Euphoberidæ, Myriapods with their body-rings produced into spines, and having a peculiar arrangement of their ventral plates. On the death of Mr Coutts, the specimen was acquired by the Museum of Science and Art, Edinburgh, and, by the kind permission of Dr R. H. Traquair, I now propose to lay the description of it before you, and to associate it with the names of Messrs Patton and Coutts, in grateful recollection of their services to science.

Genus PATTONIA, nov. gen.

Body fusiform; segments almost circular in cross section, a little more than three times broader than deep, and set with spines round their posterior dorso-lateral margins.

PATTONIA COUTTSI, spec. nov.

[Plate IV. Figs. 1-1^{e}.]

The only specimen from which the present species is described consists of the head and nine of the succeeding segments of a large and handsome Myriapod, which must have been fusiform, and nearly circular in cross section. The fragment preserved measures 40 mm. from the front of the head to the posterior end of the seventh segment. The matrix in which the remains are embedded consists of a finely-levigated dark calcareous shale, while the head and seven segments are filled in with clay ironstone, in such a manner that they retain much of their natural vaulting. Only the dorsal and dorso-lateral view of the segments is shown.

The head is 9 mm. long by 8 mm. broad at its broadest point. It is followed by a segment which is only 6 mm. broad. From this segment backwards, each succeeding one increases in breadth, till at the sixth the body has attained its maximum breadth of 15 mm. The seventh segment, the hindmost one, preserved in a state fit for study, is of almost exactly the same proportions as the sixth. From these data, it is rational to infer that only the anterior portion of a much elongated animal is preserved to us, and that the portion of its body which is not preserved tapered backwards. The head-mask, which is a little longer than broad, is pyriform, with its narrower end in front, and broadest at

about three-fourths of its length from the anterior margin. It is highly vaulted, and is divided by a deep sinuous transverse groove into two areas. The smaller of these, lying behind the groove, is rounded and vaulted in both directions, and bears a striking resemblance to the front part of a human skull, while the larger area in front, which bears the eyes and the sockets for the antennæ, reminds one of the face. The eye-spots are aggregated on two small, almost circular eminences, which rise up out of hollows situated just in front of the groove above mentioned, and about 4 mm. apart. Owing to imperfect fossilization, and to the difficulty in clearing off the matrix, the number of eye-spots upon each eminence cannot be made out.

The sockets into which the antennæ are articulated are placed in front of the eyes, but somewhat closer together, and are surrounded by raised margins. The space between the sockets and the rounded lip in front are pitted with small circular holes, from which, doubtless, sensory hairs grew during life, but which had been removed prior to fossilization. The antennæ are short, and similar to those of the recent Iulus. In the present case, only that of the right side is preserved, and that is disjointed and out of place. The three proximal joints, still attached to each other, lie bent round the lip, just within the anterior margin; while the three distal joints, also attached to one another, lie imbedded in the matrix, a little outside and beyond the right eye. The aggregate length of the six joints is 5 mm. Each segment is almost circular in cross section, and narrowest at its proximal extremity. That nearest the head is the largest, and thence they decrease in size till the fifth is reached. The terminal joint is somewhat elongated compared with the fifth, and ends in a rounded and blunt tip, which is well pitted with circular hollows, as if it had been plentifully supplied with tactile hairs (Fig. 1^a). The mouth organs have not been observed. If they still exist, they are deeply embedded in the matrix, which, at that point, is of the nature of a clay ironstone.

Body.—As already stated, only the dorsal portions of the body-rings are visible. Counting backwards from the head,

that of the first segment is small, and appears to be single, and a little narrower than the head. It is 2 mm. deep, and somewhat tumid, but could not have risen to the level of the top of the head. In this respect, and in the manner in which it is articulated with the head, it reminds one of the corresponding segment in the Polydesmidæ. The second segment is also single, and similar to the first, only it is a little deeper, and probably broader, but this cannot be demonstrated, as one side of it is telescoped into the succeeding segment. The third and succeeding segments are double, and in every respect similar to each other, with the exception that they gradually increase in size till the sixth is reached. Each consists of two tumid bands, separated by a deep transverse furrow. The band in front is much the smaller, is simple, and bears on its anterior edge the smooth, narrow rounded facet by which it is articulated to the segment in front. The hinder tumid band is larger and much more swollen, and bears on its sides the foramina repugnatoria, or openings of the "stink-glands," while its posterior margin, where it folds downwards and forwards, is raised into a strong ridge, which bears a row of circular holes, which appear to represent the bases of spines that had been broken off ere the remains were entombed in their present matrix. The seventh segment is in every respect similar to the sixth, both in dimensions and structure. The eighth and ninth segments are crushed underneath the seventh in such a manner as to prevent their study. The sternal portions of the segments are not observable, and if preserved in place are buried in the matrix.

Limbs.—These have been all broken off from the segments to which they were attached, and lie in a row, which begins near the right side of the head, and stretches obliquely outwards and backwards from it. The limbs seem to have been in a very imperfect state before being imbedded, and, owing to accidents during the freeing of them from the matrix, in which they are firmly fixed, they have been still more injured. From the fragments left, a good deal of their character can be made out. One which lies farthest from the head, and which, therefore, presumably belongs to one of the

large double segments, shows portions of four joints, measuring in all about 14 mm. in length (Fig. 1[b]). Counting from the body outwards, these represent the third, fourth, fifth, and part of the sixth joint, measuring respectively 5, 4, 4, and 1 mm. in length. They are somewhat flattened laterally by pressure, and in their present state the third joint is 1 mm. broad at its proximal and 2 mm. at its distal end, near to its articulation with the fourth joint. Some detached, short, thick, triangular joints occur, and are in all probability coxal joints, one of which measures 1·75 mm. in breadth. Another detached portion shows a sixth joint, with the attached; single claw (Fig. 1[d]). Four flattened legs lie side by side. These, which appear to belong to segments nearer the head than the limb above described, show parts of the fourth, the whole of the fifth, and part of the sixth joints. Three of these together measure 3 mm. across their fifth joints. All these joints, as well as the corresponding joints in the limb first described, are more or less pitted, showing that the limbs, especially towards their extremities, were more or less supplied with hair-like spines, as in the recent Iulus. By piecing together the evidence supplied by these scattered joints, it is apparent that the species under consideration was supplied with limbs, each of which was quite as long, or even longer, than the width of the segment to which it was attached; and if, as it is natural to infer, the sternal plates were correspondingly wide, as they have been shown to be in other described members of the family Euphoberidæ, the legs, when in use for progression, must have extended far beyond the edges of the body. For this reason, and from the fact that the articular facet at the anterior edge of each segment is very narrow, it is highly improbable that this species had the power of rolling up its body and protecting its legs in the manner adopted by the recent Iulus.

I have named the genus after Mr Patton, and the species after Mr Coutts, of whose labours we are still reaping the fruits.

Locality.—East Kilbride, Lanarkshire.

Formation.—Carboniferous Limestone.

Collector.—Patton.

PART II.

(Read 20th April 1898.)

In the first part of this paper, a brief sketch of the discovery of the remains of the oldest known air-breathing Arthropods was given. Before proceeding to describe some new forms of Millepedes from the Silurian, Old Red Sandstone, and Carboniferous rocks of Scotland, which is the main object of this paper, I purpose to give a very short account of the history of the discovery of remains of Palæozoic Myriapods.

As early as the year 1845, the late Rev. P. B. Brodie, in his "History of Fossil Insects," figured the remains of a terrestrial Arthropod from the Coal-Measures of Colebrookdale, which Professor J. O. Westwood, at that time, erroneously, as will be shown in the sequel, considered to be those "of some large caterpillar, furnished with rows of tubercles."

The late Sir J. W. Dawson was the first clearly to announce, in the year 1859, the discovery of remains of undoubted Myriapods from Palæozoic rocks. These were brought to light by him out of the famous upright hollow Sigillarian stems, exposed in the sea cliffs of Carboniferous rocks at South Joggings, in Nova Scotia.[1]

In 1868 A. Dohrn described the remains of a Millepede from the Permian rocks of the Saarbrück[2] coal-field. In the same year, Messrs Meek and Worthen began to describe the Spined Myriapods, *Euphoberia*, etc., preserved in nodules in the Carboniferous rocks of Mazon Creek, Illinois, a locality made famous by the rich treasure of Arthropod and other remains which it has yielded to investigators.[3] These, and the other American Myriapods from Joggings, were subsequently studied and classified by Dr S. H. Scudder, by whom

[1] J. W. Dawson, "On a Chilognathous Myriapod from the Coal Formation of Nova Scotia," *Quart. Jour. Geol. Soc.*, vol. xvi., figs. (London, 1859).

[2] A. Dohrn, *Verhand. d. naturh. Vereins d. Preuss. Rheinl.*, 4 Ser., Bd. v. (Bonn, 1868).

[3] F. B. Meek and A. H. Worthen, *Amer. Jour. Sci. and Arts*, (2) vol. xlvi. p. 25; "Articulated Fossils of the Coal-Measures" (Geol. Survey of Illinois, vol. iii., 1868).

our knowledge of Palæozoic Myriapods has been greatly increased, and brought to a focus.[1]

Dr Henry Woodward, in the year 1867, showed that our own Scottish Carboniferous rocks contained Myriapods.[2] Again, in 1871, he described a species belonging to the genus *Euphoberia*, of Meek and Worthen, from the Coal-Measures of Kilmaurs, in Ayrshire, under the name of *Euphoberia Brownii*, after the finder.[3]

He subsequently pointed out, with the concurrence of the late J. W. Salter, that the specimens of *Arthropleura ferox*, of Salter, were the remains of a large species belonging to the genus *Euphoberia*, and that "the peculiar caterpillar-like creature," of Brodie and Westwood above mentioned, belongs to the same species.

In the year 1882 I read a paper before this Society, pointing out that the peculiar Arthropod remains named *Kampecaris Forfarensis*, by Page, which occur in the Lower Old Red Sandstone of Scotland, belong to two genera of remarkably simply constructed Millepedes, now named *Kampecaris* and *Archidesmus*.[4]

Dr G. F. Matthew, in the year 1893, described several forms of Myriapod from the Devonian rocks of St John, New Brunswick.[5]

As already mentioned in Part I., the fossil collectors of the Geological Survey found in 1897 a fragment of a Myriapod in the Upper Silurian rocks of Lesmahagow, which belongs to the genus *Archidesmus*. In the same

[1] S. H. Scudder, "On the Carboniferous Myriapods preserved in the Sigillarian stumps of Nova Scotia," *Mem. Bost. Soc. Nat. Hist.*, vol. ii., figs. (Boston, 1873); "Archipolypoda, a natural type of Spined Myriapods from the Carboniferous formation," *ibid.*, vol. iii., pls. 10-13 (Boston, 1882); "The Affinities of Palæocampa," *Amer. Jour. of Science*, ser. 3, vol. xxiv. (New Haven, 1882); "Two New and Diverse Types of Carboniferous Myriapods," *Mem. Bost. Soc. Nat. Hist.*, vol. iii. (Boston, 1884).

[2] *Trans. Glasgow Geol. Soc.*, vol. ii. pp. 234-238, 1867.

[3] H. Woodward, "On *Euphoberia Brownii*," *Geol. Mag.*, vol. viii. (London, 1871).

[4] B. N. Peach, "On some fossil Myriapods from the Lower Old Red Sandstone," *Proc. Roy. Phys. Soc. Edin.*, vol. vii., pl. ii. (Edinburgh, 1882).

[5] G. F. Matthew, "On the Organic Remains of the Little River Group," *Trans. Roy. Soc. Canada*, sec. iv. pp. 101-111, pl. i., 1894.

year A. Macconochie added to the collection of the Geological Survey a specimen of *Kampecaris*, from the Lower Old Red Sandstone of the island of Kerrera, opposite Oban, in the district of Lorne. Many years ago Mr A. Macconochie, while collecting from the Lower Carboniferous rocks of Lennel Braes, on the river Tweed, near Coldstream, obtained from them a very complete specimen of a Myriapod. All these specimens are in the collection of the Geological Survey of Scotland, and, by the kind permission of Sir Archibald Geikie, the Director-General of the Geological Survey, I now purpose to describe the forms, which are all new to science.

Genus ANTHRACODESMUS, nov. gen.

Forms with dorsal parts of body-rings and sculpturing like those of *Polydesmus*, but with more than nineteen body segments, and with eye-spots arranged in groups.

ANTHRACODESMUS MACCONOCHIEI, n. sp.

[Plate IV. Figs. 3, 3a.]

The only specimen from which the following description is taken shows the dorsal aspect of a head and twenty-six body segments of a small form, about 26 mm. long by about 3 mm. in extreme breadth.

Head.—The head is subquadrate, with rounded angles, somewhat broader behind than in front, its greatest breadth being 2 mm. The back part of the head is well arched. The eye-spots are arranged in clusters, just in front of the posterior rounded angles, and the antennal pits are placed just in front of the ocular areas, and nearer together than them. The front of the face and upper lip are pitted, as if they had been supplied with sensory hairs. The antennæ are made up of short small joints, and are club-shaped, as in recent Millepedes. In the present case they appear to be six-jointed, but as the right antenna is broken away from the head, though its extremity is seen, there is some little difficulty in counting the number of the joints, and some may have been removed from the proximal end. Only three

of the joints of the left antenna are left, though these are still attached to the head.

Body.—The body is elongated and fusiform, though the segments are somewhat flattened, and produced into distinct lateral lamellæ, while the dorsal portion of each segment is ornamented with an embossed sculpturing, like that seen upon corresponding structures of species of the recent *Polydesmus* (Fig. 3[a]). The first segment, counting from the head backwards, is a little narrower than the back of the head, while this and the following two appear to be single, the third from the head being the deepest. All the rest of the segments are double. The body appears to attain its greatest breadth of 3 mm. about the seventh segment, and from thence it carries this breadth to within a short distance of its extremity, where it tapers somewhat suddenly towards its terminal joint, which is almost half-moon shaped, with a breadth of about 1·5 mm. at its articular base. None of the sternal arrangements are observable.

Limbs.—Most of the legs have been removed prior to fossilization, but from the few fragments left, they appear to have been constructed much after the manner of those of the recent Polydesmidæ.

Locality.—Lennel Braes, Coldstream, Berwickshire.

Formation.—Calciferous Sandstones, Lower Carboniferous.

Collector.—A. Macconochie.

Genus Kampecaris (Page).

Kampecaris obanensis.

[Plate IV. Fig. 2.]

This specific name is proposed for a small form of *Kampecaris*, from the Lower Old Red Sandstone rocks of the island of Kerrera, near Oban. The specimen, preserved in dark flagstone, is doubled together and flattened by pressure, so as to expose only the dorsal aspect of part of the back and the right side. It is slightly curved, and measures about 20 mm. in length.

Head.—The head, as viewed, is subquadrate in shape,

broader behind than in front. The eye-spots are few in number, and are arranged in groups situated near the posterior rounded angles of the head. Only the bases of the antennæ are preserved, and they seem to have been placed well forward. Anterior margin of head not seen. No mouth-organs observable, as only the dorso-lateral aspect of head is exposed.

Body.—The body consists of sixteen segments, all of which appear to be simple, but they do not seem to be alternately larger and smaller, as is the case in *Kampecaris Forfarensis*. The first four segments are smaller than the rest. All the segments appear to have been produced into lateral lamellæ, but these are not so pronounced as in *Archidesmus*. The sculpturing of the test consists of a slight granulation and occasional papillæ, on which were probably set spines during life. No legs seen.

Locality.—Kerrera, near Oban.

Formation.—Lower Old Red Sandstone.

Collector.—A. Macconochie.

Genus ARCHIDESMUS (Peach).

ARCHIDESMUS LOGANENSIS, n. sp.

[Plate IV. Fig. 4.]

This name is founded on a specimen of the anterior portion of a Myriapod, about 15 mm. long by about 5 mm. wide, showing the head followed by eleven or twelve body segments, with parts of the antennæ and several walking-limbs attached. It is flattened, and only shows the dorsal aspect. As the portion of the body preserved shows a very slight tapering, it is inferred that it belongs to what was a much-elongated creature.

Head.—The head is shaped like the ace of clubs, as shown on playing-cards. Small eye-spots are scattered over the side lobes, but the most marked feature of the head is the great size of the pits out of which the antennæ arise. The antennæ are very massive for the size of the head. Four joints of the right antenna are preserved. These pass

straight forward, and seem to increase in breadth as they recede from the head, and each joint is broadest at its distal extremity. The left antenna is bent back upon itself at the second joint, and appears to be complete, though its extremity seems to be hid underneath one of the walking-limbs. It appears to be made up of six joints, and to be constructed like that of the recent Millepedes, the joints being short and thick, and narrower at the bases than at the extremities.

Body.—The body segments, of which twelve are seen attached together, appear all to be formed after the same manner—those nearest the head are the narrowest. They are all produced into lateral lamellæ, which exhibit similar depressions to those seen in *Archidesmus Macnicoli*, as described by me, and are sculptured with a minute granulation, and furrowed by short sub-parallel wrinkle-like markings, arranged transversely to the length of the body. The dorsal scutes of four more rings detached from the body, and also from each other, occur embedded in the matrix. One of these lies just behind and a little to the right of the twelfth segment, while the three remaining ones lie to the left of the specimen, as if they had been carried forward by a current as the animal gradually decomposed before being finally covered up by sediment.

Limbs.—Several legs are seen to be still attached to the left side of the anterior part of the body. They are each longer than the breadth of the larger segment preserved, and appear to be constructed like those of the recent *Polydesmus*, which they greatly resemble, though they are somewhat larger in proportion to the body. In their present flattened state they appear nearly as broad, and, in some cases, even broader than the segment to which they seem to be attached, and were doubtless compressed laterally during life. Portions of four limbs are seen on the right side. Two of these appear to be attached to segments next the head, while two still more fragmentary ones are seen to emerge from beneath the eleventh and twelfth segments. The study of the two limbs next the head, which are composed of joints much shorter than any of the limbs seen on the left side, and those of the

first limb, shorter individually than those of the second, lead to the inference that these two are in place, and attached to the first and second segments of the body, while all those of the left side are detached, and carried bodily forward from their respective segments. The fact that the third or long joint of the most anterior limb seen on the left side covers the tip of the antenna also, strengthens this inference. Further, the massiveness and breadth of the limbs, some of which are as broad as the depth of the dorsal scutes of any of the segments, seem to indicate that the segments were single, and each only supported one pair of limbs. Although there does not appear to be an alternation of larger and smaller segments in the present form, yet its general construction shows that it is very nearly allied to *Archidesmus Macnicoli*, of the Lower Old Red Sandstone of Forfarshire; and I propose to let it remain, provisionally, in the same genus with it, till more material turns up from these older rocks.

Locality.—Logan Water, one mile west of Logan House, Lesmahagow, Lanarkshire.

Formation.—Ludlow.

Collectors.—Messrs A. Macconochie and D. Tait.

In the year 1859, a fragment of an Arthropod from the Lower Ludlow rocks of Leintwardine, in the cabinet of Mr Salwey, was figured by Messrs Huxley and Salter in plate xiii. fig. 17 of monograph i. of the "Memoirs of the Geological Survey of the United Kingdom." In the text of that memoir, page 25, Huxley says: "The fossil figured in plate xiii. fig. 17, is evidently crustacean, but it exhibits no character by which it can be identified as a part of *Pterygotus*. . . . I know of only two crustacean structures with which this body can be compared, the one is the carapace, the other is the swimming-limb of a Copepod, with its coalesced, lamellar, basal joint greatly developed." Subsequently, Dr Henry Woodward described the remains as those of an Amphipod Crustacean, under the name of *Necrogammarus Salweyi*.[1] Though I have not had the

[1] *Trans. Woolhope Nat. Field Club*, 1870.

opportunity of studying the specimen itself, yet, taking the figure by Huxley and Salter, a reduced copy of which is given in Plate IV. Fig. 6, I think there is still another view to be taken of the structures there portrayed, viz.—that they are those of a Diplopod Millepede. The middle lobe of the figure probably represents the dorsal scute of a coalesced pair of segments bearing two pairs of limbs, the coxæ of those of one side being left; the other joints of the limbs, similar to the one preserved on another segment, having been wrenched off. The structure of the remaining lobes, and their appendages, are quite in consonance with this view.

EXPLANATION OF PLATE IV.

Fig. 1. *Pattonia Couttsi;* natural size. Lower Carboniferous, East Kilbride, Lanarkshire. From specimen in Museum of Science and Art, Edinburgh.

Fig. 1^a. Right antenna of above; magnified.

Fig. 1^b. Limb of above; magnified.

Fig. 1^c. Tip of limb of above; magnified.

Fig. 1^d. Diagrammatic scheme of double segment of above.

Fig. 1^e. Diagrammatic outline to show mode of articulation of dorsal sclerite of double segments of above.

Fig. 2. *Kampecaris Obanensis;* $\frac{2}{1}$. Lower Old Red Sandstone, island of Kerrera, near Oban, Argyleshire. From specimen in Collection of Geological Survey of Scotland.

Fig. 3. *Anthracodesmus Macconochiei;* $\frac{3}{1}$. Lower Carboniferous, Lennel Braes, near Coldstream, Berwickshire. From the specimen in the Collection of the Geological Survey of Scotland.

Fig. 3^a. Eleventh and twelfth segments of above, further magnified, to show pattern of sculpture.

Fig. 4. *Archidesmus loganensis;* $\frac{2}{1}$. Upper Silurian, Logan Water, Lesmahagow, Lanarkshire. From specimen in Collection of the Geological Survey of Scotland.

Fig. 5. Head and first four segments of *Iulus Blainvillei*, recent, magnified; for comparison.

Fig. 5^a. Body segments of above, natural size, to show limbs and foramina repugnatoria, to compare with 1^d.

Fig. 5^b. Limb of above, magnified, to compare with 1^b.

Fig. 5^c. Antenna of above, magnified, to compare with 1^a.

Fig. 6. *Necrogammarus Salweyi* (Woodward); $\frac{2}{1}$. Ludlow, Leintwardine.

NEST AND EGGS OF THE SATIN BOWER-BIRD.

From a Photo. by Mr S. W. Jackson.

PLATE I.

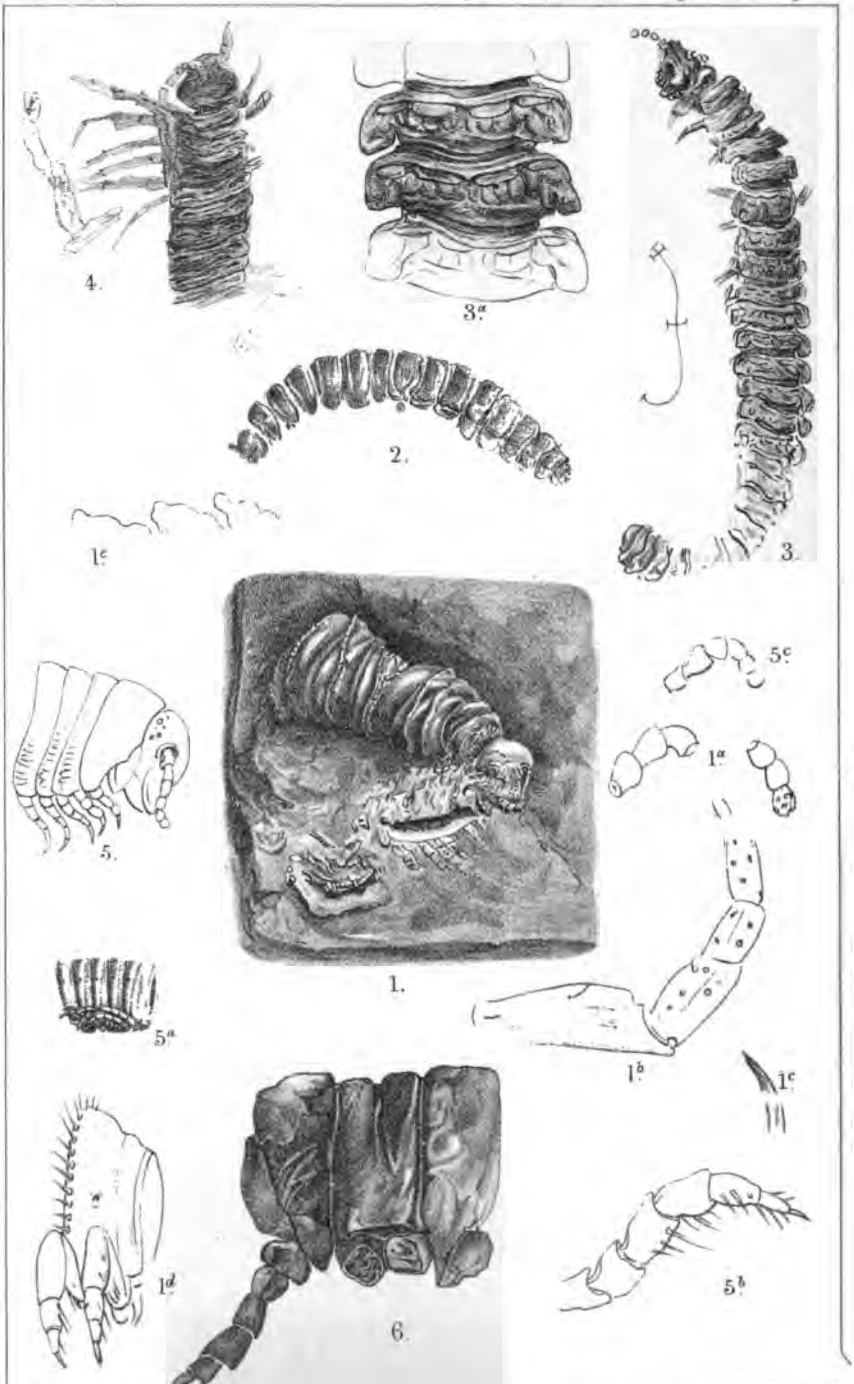
NEST AND EGGS OF THE SATIN BOWER-BIRD.

From a Photo. by Mr S. W. Jackson.

From a Photo. by Mr H. H. Johnston.

BOWER OF GREAT BOWER-BIRD.

PLATE IV.



B. N. Peach.

PALÆOZOIC MYRIAPODS.

PROCEEDINGS

OF THE

ROYAL PHYSICAL SOCIETY.

SESSION CXXVIII.

Wednesday, 16th November 1898.—Mr B. N. PEACH, F.R.S., President, in the Chair.

Owing to the illness of Mr Andrew Wilson, the retiring Vice-President, the customary Opening Address was on this occasion omitted.

IX. *Results of Meteorological Observations taken in Edinburgh during* 1898. By R. C. MOSSMAN, F.R.S.E., F.R.Met.Soc.

(Read 15th March 1899.)

The data discussed in this paper are deduced from bi-daily observations of the standard instruments read daily at 9 A.M. and 9 P.M., and controlled by the automatic methods of registration which were fully described in last report. The weekly and monthly returns, to the number of one hundred and forty, continue to be regularly forwarded to the Scottish Meteorological Society, the Registrar-General for Scotland, and the Meteorological Office; and, in addition, a large number of private inquiries have been answered. During the year a number of experiments with kites of the Blue Hill pattern have been made, with a view to the scientific exploration of the upper air. These experiments have, on the whole, been successful, and the few failures have served to indicate the

directions in which improvements in the apparatus are required. No instruments have as yet been sent up, but an elaborate and costly meteorograph has been ordered from M. Richard, of Paris. This instrument is being made of aluminium, and will weigh less than three pounds. It consists of a barometer, a thermometer, and a hygrometer, which all record their readings automatically on one cylinder turned by clockwork in eight hours. Scotland will thus at an early date be able to join in the international scheme of aerial investigation inaugurated by Mr A. Laurence Rotch, director of the Blue Hill Observatory. The success of the Edinburgh kite-flying experiments, so far as carried out, is entirely due to the liberality and energy of Mr John Anderson (late of Owensboro, Kentucky), who has directed operations from the first. Another gentleman interested in the work has kindly presented the costly meteorograph already referred to, thus completing the equipment. To these two gentlemen the author presents his cordial thanks.

Remarks on the Meteorology of 1898.

January.—A phenomenally mild month, the mean temperature of 44°·6 being the highest on record since the commencement of meteorological observations in Edinburgh in 1764. The nearest approach to the above high mean temperature was 43°·8, in 1796. Other very mild Januarys were those of 1846, 1882, and 1890, with mean temperatures of 42°·1, 42°·0, and 41°·6 respectively. The wind during the month blew almost wholly from the west and south-west. The exceptional warmth was unequally partitioned between the day and night temperatures, the nights relative to the average being 2° warmer than the days. The shade maximum exceeded 50° on no fewer than eleven days, while on no occasion was there any frost registered. The least number of shade frosts previously recorded in January during the last ninety-five years was four, in the year 1882. The maximum shade temperature of 56°·5, recorded on the 19th, was the highest in January since the 31st, in the year 1846; while the mean temperatures of the 19th and 30th,

viz., 51°·8 and 52°·0 respectively, were higher than anything experienced during at least the last hundred years. No snow fell during the month, and the precipitation, all in the form of rain, was under an inch. The mean barometric pressure was much above the normal, but sunshine was greatly below the average. The temperature of the soil was very high and equable throughout the whole month.

February.—The characteristic features of the weather of February were a high mean temperature, rather low pressure, and but little rainfall. Sunshine was in excess of the normal, the total for the month — 90 hours — being the greatest recorded in February since 1880. The winds were almost wholly from the west, and blew with the force of a gale on the 1st and 12th. On the 6th the unusual phenomenon of a thunderstorm took place, at 3.31 P.M. Heavy snow and hail showers and a great darkness accompanied the thunderstorm. Snow also fell on the 21st and 26th.

March.—During March most of the meteorological elements agreed closely with their normals, but the rainfall was again in defect, less than one-third of an inch falling during the first twenty-five days. The last week was, however, stormy and unsettled, with frequent showers of snow, sleet, and hail. There was a fog on the 7th, and a brilliant aurora on the 15th.

April.—The mean temperature was 2°·7 above the average, being the seventh consecutive month with a mean above the average of one hundred and thirty-four years. The warmth was unequally partitioned between the day and night values, the mean maximum being 1°·8, but the average minimum as much as 3°·6 in excess of the normal, the nocturnal warmth being thus a noticeable feature. Rainfall was just the average, but bright sunshine (94 hours) much below the mean. Distant thunder was heard at 2.45 P.M. on the 10th, and a solar halo was seen on the 19th.

May.—The weather of May was without any special feature, having the average sunshine, humidity, and rainfall. Mean temperature was, however, a little over a degree below the average. Thunder and lightning were observed on the 3rd, hail and lightning on the 4th, while sleet and hail fell

on the 31st. On the 11th the barometer fell to 28·836 inches, the lowest in May for twenty years.

June.—Mean temperature 0°·3 above, and rainfall 34 per cent. below the average. Although but little rain fell, there were a large number of very damp and muggy days, especially from the 9th to the 17th, during which time the wind blew from the east. Westerly winds prevailed during the first week and last fortnight of the month. No rain fell from the 7th to the 16th, while the heaviest daily fall was only 0·28 inch, on the 3rd. Hail fell on the 1st, thunder heard on the 21st, and a slight thunderstorm on the 24th. A dense wetting mist was experienced on the 9th and 10th.

July.—During July the weather was dry, with a good deal of sunshine, but no great heat. Rain was only 38 per cent. of the normal, and there were only three wet days from the 6th to the 26th. The mean temperature was just the average, the days being about a degree above, but the nights a degree below their respective averages. The outstanding feature of the meteorology of the month was the very high mean barometric pressure, the highest in July since 1863. There was a thunderstorm, with heavy rain, at 2.15 P.M. on the 28th.

August.—During August, pressure, rainfall, sunshine, and humidity were normal, but the mean temperature was 1°·2 above the average. The 9 P.M. temperature recorded on the 12th—viz., 69°—was unusually high, there being only three higher 9 P.M. values in August since 1857. There was a thunderstorm, with heavy rain, at 7.55 A.M. on the 16th; while during a thunderstorm on the 30th, 1·42 inch of rain fell in four hours. Hail fell on the 28th inst. Solar halos were seen on the 9th and 15th.

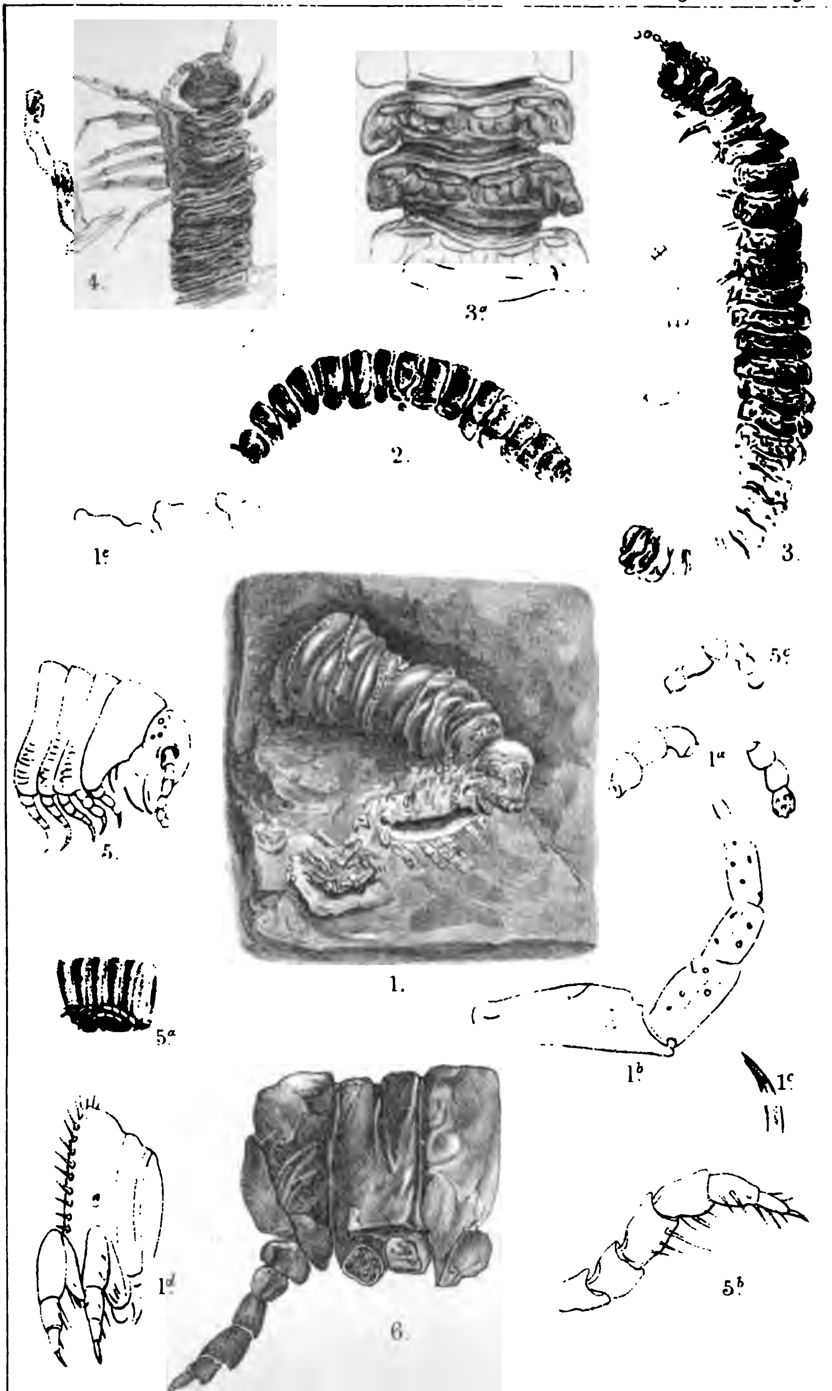
September.—The most noteworthy feature of the weather of September was the phenomenally warm spell which prevailed from the 3rd to the 17th of the month, the mean temperature for these fifteen days being 63°·6, or 8°·5 in excess of the normal. From the 4th to the 6th the weather was excessively hot, the maxima being respectively 82°·0, 82°·8, and 80°·0; while the minima were 59°·0, 57°·6, and 62°·6. The mean temperature was 70°·5 on the 4th, 70°·2 on

the 5th, and 71°·3 on the 6th, this being the first time on which each of three consecutive days had a mean temperature in excess of 70°. This very nearly happened in June 1826, when the average for the 28th was 74°·0, for the 29th 73°·5, and for the 30th 69°·0. The maximum readings on the 4th and 5th were in excess of anything recorded in September since 1838, when a value of 84°·0 was registered on the 9th of the month. The nocturnal warmth from the 3rd to the 8th was very unusual, the mean of all the minima being 60°·2. The temperature never fell below 62°·0 on the 3rd, 62°·6 on the 6th, and 60°·6 on the 7th. The minimum value on the 6th was the fourth highest recorded in any month during the last fifty-seven years, the warmest of all being the night of August 4th-5th, 1890, when the lowest reading was 63°·3. The unusual warmth was aggravated by the great humidity, the air for several days being nearly saturated, more especially at night. Taking the heat wave in its various aspects, it seems to have been the most noteworthy experienced since the very warm June of 1826.

October.—This was a very mild month, the mean of the day temperatures being 2°·5 above, and of the night temperatures 5°·1 above the average. The mean temperature of 51°·0 is the highest in October since 1857. The month opened with fine dry warm weather, the maximum shade temperature of 70°·2, recorded on the 4th, being the highest in October since 1845. The long spell of dry weather broke up on the 15th of the month, the rainfall for the second half being three and a half inches. Sunshine was below the average, and rainfall 54 per cent. above the mean. Dense fogs were recorded on the 5th and 29th.

November.—November opened with warm and wet weather, an inch and a half of rain being recorded on the first three days of the month. Temperature was very high on the 2nd, a maximum of 61°·0 being registered, this being the highest in November since 1881, and only exceeded in three of the last fifty-eight Novembers. Mean temperature was 1°·6 above, and rainfall 56 per cent. in excess of the average. Sunshine was only half the mean, and there was a dense fog daily from 9th to 12th. Towards the close of the month a

PLATE IV.



PALÆOZOIC MYRIAPODS

	Rainfall.					Relative Humidity. Saturation = 100.				Vapour Pressure.			Dew Point.			Solar and Terrestrial Radiation.							
	Total Fall.	Max. in 24 hours.	Diff. from Average 122 years.	No. of days on which ·01 in. or more fell.	Diff. from Average 1877–1896.	Mean at 9 A.M.	Mean at 9 P.M.	Mean, 9 A.M. and 9 P.M.	Diff. from Average 1862–1896.	At 9 A.M.	At 9 P.M.	Mean.	At 9 A.M.	At 9 P.M.	Mean.	Maximum in Sun.	Mean.	Greatest Excess over Shade Maximum.	Average Excess over Shade Maximum.	Minimum on Grass.	Mean.	Greatest Difference from Shade Min.	Mean Difference from Shade Min.
	Ins.	Ins.	Ins.	Days.	Days.	%	%	%	%	In.	In.	In.	°	°	°	°	°	°	°	°	°	°	°
January, .	0·84	0·19	− 1·59	13	− 3	82·5	82·9	82·7	− 4·1	·247	·248	·248	39·7	39·8	39·7	86·0	63·1	30·9	14·6	28·7	36·4	7·4	4·3
February, .	1·02	0·21	− 0·94	13	− 1	77·5	78·4	78·0	− 8·4	·182	·192	·187	31·6	33·2	32·4	95·3	77·8	51·1	33·0	20·6	31·2	7·3	3·8
March, . .	1·22	0·50	− 0·76	15	0	79·3	81·9	80·6	− 3·5	·197	·202	·200	33·7	34·2	34·0	109·3	85·5	55·9	38·7	20·7	32·1	7·5	2·9
April, . .	1·91	0·57	− 0·15	15	+ 1	79·9	81·5	80·7	+ 0·2	·262	·254	·258	41·3	40·2	40·8	113·9	94·3	56·5	40·5	25·0	38·3	7·3	2·9
May, . . .	2·34	0·57	+ 0·25	18	+ 4	72·9	81·0	77·0	− 1·1	·265	·256	·260	41·6	40·7	41·1	120·3	104·3	63·0	48·3	29·5	39·0	5·5	2·1
June, . . .	1·39	0·28	− 0·71	12	− 2	75·8	83·1	79·4	+ 2·0	·348	·337	·343	48·6	47·5	48·0	125·0	113·3	61·8	49·6	39·4	46·6	4·9	1·7
July, . . .	1·28	0·28	− 2·08	10	− 8	74·2	78·8	76·5	− 2·6	·364	·356	·360	50·0	49·3	49·6	132·6	114·1	63·7	47·2	40·0	47·1	4·7	2·8
August, . .	3·30	1·58	− 0·18	18	− 1	79·1	80·4	79·7	− 1·8	·396	·399	·398	52·2	52·4	52·3	132·9	109·8	58·7	42·2	40·0	48·2	6·9	3·1
September, .	2·21	0·75	− 0·71	14	− 2	83·6	85·5	84·6	+ 2·0	·401	·395	·398	52·0	51·6	51·8	131·2	105·5	53·5	40·5	36·3	47·5	5·5	3·2
October, . .	3·70	1·10	+ 1·30	14	− 3	86·6	86·9	86·8	+ 1·0	·321	·317	·319	46·5	46·1	46·3	105·0	84·1	47·0	28·5	36·0	43·8	6·3	2·7
November, .	4·11	0·90	+ 1·47	20	+ 3	84·7	87·2	86·0	− 0·8	·229	·245	·237	37·1	39·1	38·1	83·8	61·3	31·8	14·1	17·0	34·5	8·2	3·3
December, .	1·91	0·29	− 0·57	19	+ 3	82·7	81·4	82·0	− 4·4	·252	·238	·245	39·8	38·4	39·1	84·0	57·6	31·4	9·4	22·2	36·1	7·7	3·6
Year, . . .	25·23	1·58	− 4·67	181	− 9	79·9	82·4	81·2	− 1·8	·289	·287	·288	42·8	42·7	42·8	132·9	89·2	63·7	34·0	17·0	40·1	8·2	3·0

	Bright Sunshine for Hour ending Greenwich Time.																	Percentage of possible Duration.	Difference from Average 30 years.	Greatest Percentage of possible in 1 Day.	No. of Sunless Days.	Difference from Average 30 years.	Cloud 0–10.			Mean Wind Velocity per hour.
	A.M.								P.M.								Total.						9 A.M.	9 P.M.	Mean.	
	5	6	7	8	9	10	11	Noon.	1	2	3	4	5	6	7	8										
	Hrs.	Hrs.	Hrs.	Hrs.	Hrs.	Hrs.	Hrs.	Hrs.	Hrs.	Hrs.	Hrs.	Hrs.	Hrs.	Hrs.	Hrs.	Hrs.	Hrs.	%	%	%						Mls.
January,	...	...	...	...	0·4	0·9	3·7	4·2	4·6	4·5	3·1	1·2	...	...	...	...	22·6	10	−11	58	13	+ 2	8·4	6·4	7·4	8·0
February,	...	...	...	1·0	5·7	11·2	14·1	15·9	13·2	14·5	10·0	4·4	...	...	...	...	90·0	34	+ 8	75	3	− 2	5·1	4·0	4·6	10·4
March,	...	...	...	2·9	10·5	11·0	15·7	15·8	11·8	9·1	9·7	6·2	2·8	0·6	...	...	96·1	26	− 4	79	2	− 5	5·8	6·1	6·0	7·9
April,	...	0·2	2·6	4·0	7·0	10·4	11·6	10·8	10·3	11·1	10·0	7·6	5·8	2·8	...	...	94·2	22	− 8	65	8	+ 3	7·4	5·9	6·6	5·2
May,	1·8	9·9	12·6	13·2	13·8	14·3	14·8	13·8	12·6	11·4	10·8	10·5	7·6	7·5	3·0	0·4	158·0	31	− 1	77	2	− 2	7·5	6·5	7·0	6·3
June,	2·8	7·2	7·8	10·0	9·8	12·0	11·9	11·8	11·3	11·8	12·8	9·2	8·2	8·6	7·2	1·0	143·4	27	− 1	83	3	0	8·2	7·2	7·7	5·7
July,	3·9	8·7	9·9	11·7	12·4	14·2	14·3	15·1	14·9	16·3	16·0	15·7	14·6	12·1	11·4	1·1	192·3	36	+ 7	82	2	− 2	6·8	6·2	6·5	6·9
August,	0·8	5·1	9·8	14·4	14·6	14·5	13·4	11·6	13·0	11·2	10·2	7·4	8·7	5·6	2·9	...	143·2	31	+ 1	84	4	− 1	7·3	7·1	7·2	7·7
September,	...	...	...	2·0	7·0	11·6	11·4	11·8	11·8	9·9	12·7	10·8	8·2	4·4	...	...	101·6	26	− 5	75	3	− 1	7·1	5·6	6·4	5·9
October,	...	...	...	0·2	2·2	6·0	7·4	7·7	9·4	10·0	10·5	7·8	2·8	...	...	...	64·0	20	− 9	74	13	+ 6	7·6	7·3	7·4	9·5
November,	...	...	...	...	...	0·2	3·0	6·1	6·2	6·2	4·1	1·4	...	...	...	...	27·0	11	−13	44	15	+ 6	8·1	6·4	7·2	7·7
December,	...	...	...	...	...	...	0·6	1·6	3·1	2·7	0·9	0·5	...	...	...	...	9·4	4	−15	34	19	+ 5	7·2	5·8	6·5	11·3
Year,	9·3	31·1	42·7	59·4	83·4	106·3	121·9	126·2	122·2	118·7	110·8	82·7	58·5	41·6	24·5	2·5	1141·8	25	− 2	84	87	+ 9	7·2	6·2	6·7	7·7

Wind from Observations made at 9 A.M. *and* 9 P.M. *Number of Days it blew from certain directions.*

	N.	N.E.	E.	S.E.	S.	S.W.	W.	N.W.	Calm or Variable.
January,	0	0	1	2	2	9	15	0	2
February,	1	0	1	1	0	1	20	3	1
March,	0	3	3	1	1	2	15	2	4
April,	0	1	7	2	2	3	11	2	2
May,	0	0	8	1	1	2	10	8	1
June,	1	1	7	1	1	3	14	0	2
July,	1	1	7	1	1	0	17	1	2
August,	1	3	4	0	0	2	17	3	1
September,	0	1	4	4	1	1	14	2	3
October,	0	1	6	4	1	2	12	2	3
November	1	3	5	2	2	2	10	2	3
December	0	0	0	1	0	2	24	2	2
Year,	5	14	53	20	12	29	179	27	26
Per cent.,	1	4	14	6	3	8	49	8	7
Difference from Average 1764-1896,	-3	-3	-4	+1	-2	-7	+14	+1	+3

Number of Times the following Phenomena were observed.

	Gales.	Halos.	Thunder-storms.	Lightning only.	Aurora.	Snow.	Hail.	Frost in Shade.	Frost on Grass.	Mist or Fog.	Dew.	Hoar Frost.
January,	3	2	0	0	0	0	0	0	8	0	0	1
February,	4	1	1	0	0	3	3	8	19	0	1	3
March,	2	1	0	0	1	7	5	10	19	1	1	7
April,	0	2	1	0	0	0	1	1	4	0	3	0
May,	0	3	1	2	0	0	3	0	4	1	3	0
June,	0	0	2	0	0	0	1	0	0	2	1	0
July,	0	1	1	0	0	0	0	0	0	0	0	0
August,	0	2	2	0	0	0	1	0	0	0	2	0
September,	0	1	0	1	1	0	0	0	0	0	6	0
October,	2	0	0	0	0	0	0	0	0	2	4	0
November,	1	0	2	0	0	3	2	4	8	4	1	6
December,	2	3	0	0	0	1	0	3	9	0	0	2
Year,	14	16	10	3	2	14	16	26	71	10	22	19
Difference from Average 1770-1896,	-15	?	+4	?	-2	-7	+6	-39	?	-5	?	?

	Earth Thermometers. Read Daily at 9 A.M. Mean Temperature. 3 ins.	12 ins.	22 ins.	Air Temp. at 9 A.M.	Variability of Temperature. 3 ins.	12 ins.	22 ins.	Air Temp. at 9 A.M.
	°	°	°	°	°	°	°	°
January,	41·4	41·9	41·3	45·0	2·8	0·6	0·4	4·8
February,	37·2	39·8	40·2	38·0	1·9	0·7	0·5	4·7
March,	38·6	40·5	40·2	39·7	1·6	0·6	0·3	3·4
April,	46·6	46·6	44·9	48·3	1·6	0·7	0·4	2·7
May,	50·1	50·1	48·3	50·9	1·5	0·6	0·4	2·7
June,	56·1	55·5	53·1	56·5	1·4	0·7	0·4	4·0
July,	58·5	58·4	56·9	58·5	1·8	0·6	0·3	3·7
August,	57·7	58·2	57·5	59·0	2·2	0·6	0·2	3·7
September,	55·6	56·8	56·2	57·2	2·2	0·6	0·4	4·3
October,	50·8	52·3	52·1	50·9	1·5	0·3	0·3	3·1
November,	41·7	44·8	45·7	41·6	2·0	0·8	0·4	5·2
December,	41·5	42·2	42·6	44·8	3·2	0·7	0·3	5·7
Year,	48·0	48·9	48·2	49·2	2·0	0·6	0·4	4·0

X. *Solar Energy in Relation to Ice.* By J. G. Goodchild, F.G.S., F.Z.S.

(Read 20th April 1898; received for publication April 1899.)

A large number of the natural processes with which the geologist is concerned may be said to arise chiefly from the interaction of the two opposing causes, Solar Energy and Gravitation. This is especially true of ice; and as there has been much difference of opinion with regard to the relative proportion in which, in this case, these two factors divide the work, it may serve a useful purpose if some of the facts and inferences connected with glacier ice are passed in review.

Glacier ice was formerly snow; snow came from aqueous vapour; aqueous vapour represents what was once water—sea-water chiefly; and that water was distilled from the broad surface of the ocean by the action of the Sun. Therefore, without the action of the Sun, as Tyndall and others have remarked, there could be no glaciers. Glacial conditions on one part of the earth are, consequently, the natural correla-

tives of tropical conditions on another. This must always have been the case, at every period of the Earth's history after our atmosphere had passed into its present state. What is called a glacial period is not necessarily a period of extreme cold. It is really nothing more than the result of a combination of geographical conditions, through which large quantities of aqueous vapour are distilled by the Sun's heat at one part, transported chiefly by the winds to another region, where the vapour is congealed into snow, and where it remains in quantities which are in excess of those removed by melting. In other words, glacial conditions may be said to be those which occur where, each year, more snow falls on the lowlands than is removed by melting. In this sense there is still a glacial period in the Antarctic regions, and also in Greenland and the parts near; but there is not a glacial period in many other parts where the temperature is much lower, because the air in these latter districts is drier, and snow does not fall to an extent sufficient to give rise to glaciers.

The conditions that give rise to perennial snow on the lowlands are very complicated, and would need considerable space for their full discussion. But the inter-relationships of such of the more important factors as this paper is concerned with may be briefly noticed with advantage. First of all, it is considered that, in the absence of any heat from external sources, the atmosphere would have a temperature of $-490°$ F., and it would help us to gain a clearer view of what climates are if we were to keep this in mind. It is, of course, mainly due to the action of the Sun that the temperatures of those parts of the atmospheric envelope which are next the Earth range a little more or a little less than 550° F. above that frightfully-low point. It is not difficult to compute what share of the total sun-heat that reaches the Earth should be received per annum within any given latitudes; and, indeed, maps have been constructed which show the "climates" that, in the absence of any modifying causes, would characterise the latitudinal zones. But, as a matter of fact, the actual distribution of heat by no means accords with these "theoretical" or "astronomical" climates so

marked out, as any map of the world giving Isabnormal lines will at once show. Considerable modifications arise through geographical conditions, such as those connected with the proximity of extensive uplands and plains, and with the relative position in relation to the prevailing winds, or to extensive areas of land or of water. All of these factors are very largely concerned in keeping the centre of oscillation of the temperature at any given spot above or below the theoretical mean for that latitude. There are also many factors which perhaps may be regarded as of minor importance, but which, nevertheless, take a more or less important share in the work of swaying the climatal balance one way or another. These are already well known to even beginners in the study of meteorology; but their connection with other factors which are not so generally recognised, or whose importance in the present connection has been overlooked, is so close that they may well be restated here. Amongst these it has long been known that both the specific heat and the latent heat of water and ice play an important part. It requires a much larger quantity of heat to raise a given quantity of water to a certain temperature than it does of any other substance; and water is also much longer in heating up to a given temperature, or in cooling below it, than any other body. As a consequence of this slow rate of cooling, one could convey a given quantity of warm water to a greater distance before it cooled down to a particular temperature, than one could the same quantity of any other substance warmed to the same extent at the outset. Also, it requires an enormous amount of heat to vapourise water; and although the facts and figures relating to this are now generally well known, it may serve a useful purpose to repeat them here:—To heat a pound of sea-water 1° F. requires nearly ten times as much heat as would raise 1 lb. of iron 1° F. (the specific heat of iron being ·1138). To convert 1 lb. of water into aqueous vapour requires nearly one thousand (965·7) times as much heat as would raise that 1 lb. 1° F. Hence, to convert 1 lb. of sea-water into vapour would require about as much heat as would suffice to raise 5 lbs. of iron 2000° F., which is its fusing point. So that, to produce 1 lb.

of ice there has been as much sun-heat employed as would suffice to melt 5 lbs. of cast iron.

Some other facts and figures showing the connection between Solar Energy and the formation of ice may be advantageously given here. The sun-heat at the Equator on the day of the Equinox, on each square foot of the surface, is equivalent to 1,780,477 foot-pounds. That is to say, from each square foot of the ocean, then, and there, the Sun's heat gets up steam sufficient to raise a ton weight to a height of nearly eight hundred (794) feet. And the total heat received per annum by the Earth from the Sun is equivalent to 217,316,000,000,000 horse-power. In looking at a glacier or an iceberg, one is apt to forget the enormous amount of solar energy that has been expended in the formation of the mass in question.

When the fierce rays of the tropical Sun beat upon the broad surface of the Atlantic, they do not all penetrate to any great depth. The actinic rays, and also the light rays, speed their way downwards through a vast depth of the water, diminishing in energy but little as they go. But the rays of greater amplitude, or those longer and slower ethereal undulations to which heat is due, are nearly all intercepted quite close to the surface. As a familiar illustration of this fact, which is of much importance in the present connection, reference may be made to the water-cell used in the optical lantern. In this a thickness of only half an inch of pure water will suffice to cut off nearly the whole of the heat-rays from such an illuminant as lime raised to incandescence by the oxyhydrogen flame, or even from that most powerful of all artificial sources of heat and light, the electric arc. The *light* passes through the water, but the *heat* is stopped. So, in nature, nearly all the heat-rays of the Sun are intercepted by the top layers of the sea-water, which, accordingly, are the only parts directly warmed by the Sun. It is, of course, only from the surface that evaporation takes place, and it may be as well to remind the reader that evaporation takes place at all temperatures—though most, of course, at those which are highest, and from ice and snow as well as from water.

The same energy which evaporates the sea-water sets the winds in motion; and one of the results of this manifestation of Solar Energy is, generally, that the prevalent winds not only drag the surface layers of sea-water along with them in the same direction as they are moving themselves, but that they are also the chief agents concerned in carrying forward the aqueous vapour which the Sun's heat has just before distilled. As the winds trail the upper layers of warm sea-water after them, and as, at the same time, they waft the aqueous vapour from torrid zones to temperate, or from temperate to frigid, they are themselves constantly receiving heat from both of these sources in quantities which serve to maintain their temperature at a higher point than would otherwise be the case. As, further, their high temperature enables them to take up more aqueous vapour as they advance, they arrive at our shores abundantly charged with both sensible and latent heat. The slow rate at which water parts with its heat acts as an important factor in this case. It is well known that the sea does not reach its maximum surface temperature until well into August—nearly two months after the sun reaches it maximum declination; and also that, owing to its very slow rate of cooling, the sea-water has not parted with all the heat absorbed during the previous summer until well on into February. In the mean time, the winds have trailed the waters which have been heated in low latitudes many degrees farther north, and have, in like manner, transported the warm water from these latter places to higher latitudes, and so on; the water warmed in each zone of latitude being transferred from that to the zone adjoining farther north. By thus working, as it were, in relays, such combined aqueous and aerial currents as the "Gulf Stream" convey enormous stores of heat to north-western Europe.

It has not been clearly proved that any of this heat that reaches our shores actually originated in the Gulf of Mexico, or perhaps within the Tropics at all; nor is it certain, even if that were the case, that the heat that is conveyed to us by the "Gulf Stream" represents the effects of Solar Energy which had been in operation only a few months before. No

doubt the winds do in time bodily transfer to our shores water which may have been at one time beneath the Equator; but it is by no means clear that such a transfer could take place in so short a time as a few months. The same remarks apply also, though with much less force, to the aerial components of the "Gulf Stream." These are, of course, primarily set in motion by solar energy, and their subsequent directions of movement are determined by very complicated factors, one of which must be briefly noticed here, on account of its bearing upon the formation of snow. Aqueous vapour is lighter than atmospheric air, in the proportion of 625 to 1000. Hence air charged with aqueous vapour tends to rise, while dry air has a corresponding tendency to fall. So at no great distance from an area where a copious evaporation is in progress, there must always be an area where there is a certain amount of down-draught of the drier air from the upper and colder regions of the atmosphere,—the two conditions are necessarily correlative to each other. It is true that it is often difficult, in the present state of our knowledge, to state exactly what would happen under any given combination of circumstances like these, but the broad principles undoubtedly hold good. What we are concerned with at present, however, is the fact that when aqueous vapour is condensed into rain it gives out to the air around it exactly the same quantity of heat as was used up in the first instance in converting the equivalent weight of water into the gaseous condition. That is to say, each pound weight of rain (a trifle under a pint) liberates sufficient of its latent heat of evaporation to the air around it as would suffice to melt five pounds of cast iron. And, as the specific heat of dry air is ·2669, a very large volume of air is warmed by the process. It follows from this that the condensation of a single grain of aqueous vapour liberates sufficient of the once-latent heat to warm one cubic foot of air 7°·25 F. As a result of the condensation on the west coast of Ireland, Dr Haughton estimated that the quantity of latent heat set free by this means is equivalent to nearly half of the heat derived from the Sun. A large part of this latent heat is, of course, used up directly in raising the

temperature of the cold currents of air, which are, so to speak, continually waiting over our heads for an opportunity to descend and chill our atmosphere to their own icy temperature.

It will be evident, from a consideration of these facts, how delicately adjusted our climatal balance must be, and how enormous must be the expenditure of Solar Energy required to maintain the balance of temperature. A very slight relaxation of Solar Energy suffices to turn this balance in the wrong direction, and, by letting in icy-cold currents from above, or by diverting the "Gulf Stream," to permit our climate to relapse into the sub-frigid condition proper to its latitude.

It often snows on the Highland mountains when it is raining on the low grounds of western Scotland, and when, perhaps, there is neither rain nor snow on the east. Also, it is often the case that snow lingers from year to year in shady spots at high elevations, as for example, in the Cairngorms or on Ben Nevis. If these mountain summits stood higher by only a few hundred feet, there would probably be twice as much snow as falls there now, and some of that snow would certainly lie. Now, if the whole of western Europe were elevated to about that level, something more than these things would happen. Under these conditions the aqueous component of the "Gulf Stream" would be more than a hundred miles distant from the western shores of the Scottish mainland. What is now the North Sea would be a broad lowland, with the Rhine flowing northwards into the Atlantic at a point somewhere between the north of Shetland and the south of Norway. Under these conditions of elevation there could be no sidewash (as we may term it) from the warm waters of the Atlantic into the North Sea, the Irish Sea, and the English Channel. Moreover, between the mainland of Scotland and the sea margin to the west there would intervene a wide plain with only a few eminences of any great elevation. Under such conditions as these, which almost certainly represent the geographical conditions that prevailed during the greater part

of the Glacial Period, our climatal conditions would be very different from what they are at present. Fuschias could not then grow to the size of small trees, as they do out-of-doors now in islands off the west of Scotland. Nor would palm trees grow and grapes ripen as they do in those same parts. With the aqueous component of the "Gulf Stream" more than a hundred miles distant, a very marked lowering of the winter temperature must have set in. But the aerial component would probably remain in full force. It must have drifted, under these conditions, across the "continental shelf" to the Hebrides, and thence to the Highland mountains, much as it does now. But the effects would be essentially different. There would be on the western margin a wide belt where much of the aqueous vapour would be chilled into fog; within that belt another of varying width in different parts, where the precipitation took the form of rain; and within that still, and extending to the mountain centres, a zone where instead of rain, there fell more or less snow.

Now Western Europe during the Glacial Period did, almost certainly, stand several hundred feet higher above the sea-level than it does at the present day. And I wish to emphasise the opinion that, with the land at that level, and with the "Gulf Stream" acting much as it does at the present day, we should have all the conditions needful to bring about a Glacial Period in both Britain and Scandinavia, and that there is no need to invoke any other cause to explain all the known facts relating to that remarkable episode.

With a copious precipitation, and its concomitant liberation of heat, there would seem, at first sight, to be present on our shores all the conditions for the amelioration, rather than for the deterioration, of our climate. Why, then, it may be asked, did it happen during the Glacial Period that climatal conditions went on from bad to worse? To give a satisfactory answer to that question, requires that we should first consider some additional factors connected with Solar Energy in relation to Ice. One of the most important of these lies in the fact that different substances warm up at different rates in sunshine; and another is, that the rays of

the Sun do not warm dry and clear air on their way through it, but have to reach the earth first and warm something there, which something in its turn warms the air, which is thus heated by the Sun only in a roundabout way. And this fact is quite independent of what the temperature in the sunshine may be. When the Sun's rays fall upon a stone, for example, the surface of this is heated, and from that there is radiated heat undulations of a longer and slower kind than those which came direct from the Sun, and it is these which are endowed with the property of heating the air in contact with the stone. There is a difference in the original quality of the heat direct from the Sun, as compared with what we may term the "second-hand" heat given back by the stone. Air, therefore, is warmed by radiation from a land-surface, if that surface is not covered by snow or ice, and is not warmed over a surface which is so covered. It follows from this that the temperature of the air over a snow-covered surface cannot rise above the freezing point, be the temperature in the sunshine what it may. The result we are concerned with is that solar radiation produces no effect upon the climate in such a case; and, furthermore, that the air, even beyond the margin of the snow, is also chilled; so that the area where the precipitation takes the form of snow, instead of that of rain, tends to enlarge its boundaries. Notwithstanding the fact that the Sun's rays during the Glacial Period may well have been at least as hot as they are now, and on the mountain summits must have been even hotter, on account of their greater elevation, yet, once started, these icy conditions tended to affect an increasingly larger area, spreading outwards from the mountain tops to their lower slopes, and eventually from them to the lowlands. The warmth arising from the condensation was, therefore, counteracted by the chill from the snow, as well as by frequent down-draughts of icy cold air from the upper regions of the atmosphere. So the glaciers increased in size, and, presently, coalesced with their neighbours. Then the conjoined streams extended far from their originating centres, and covered an ever-increasing area of the lowlands; until, in the end, they enlarged to such an extent that all Britain,

except the southern part of England, was swathed in one vast mantle of ice.

Another question now arises: How came it that these vast confluent sheets of ice radiated to so great a distance from their centres of dispersal? So far as Scotland is concerned, there are many reasons for believing that these centres of ice-dispersal coincided, nearly, but not quite, with the centres of the areas where there is the greatest winter rainfall now. A line passing through these centres does not coincide with the watershed, but lies to the east of it in the districts north of Glen More, and to the west of it on the south of that line of depression. A similar line marked the direction of the main axis of dispersal of the ice during the Glacial Period. The movement of at least the higher parts of the ice in the north-west Highlands of Scotland commenced, at the climax of the Glacial Period, on the eastern slopes of the mountains (for a reason which we shall presently consider), and was continued westward up their slopes and over their summits in the direction of the Atlantic. It is possible that this westward movement may have extended to the middle or even to the lower strata of the ice. In the south-east Highlands, the line of ice-shed extended through the Cairngorms, south-westward across the main watershed, and then southward, keeping some distance to the west of that line; so that the branch of the ice-sheet that filled the basin of the Forth originated in the mountains of Argyllshire, far to the west of the head-waters of any branches of the Forth. The feeders of the ice of the Forth basin, therefore, must also have travelled uphill over part of their course. Why they did so is difficult to explain satisfactorily on any theory that has yet been put forward. The difficulty is increased when we consider the now well-known fact that a continuous mass of solid land-ice extended from the mountains of Scandinavia across what is now the North Sea, and well on to what are now the maritime parts of eastern Scotland. What was the nature of the agent that forced extensive sheets of ice to flow to so great a distance from their birthplace? Not gravitation, surely. If gravita-

tion were the principal cause of the movement, and if we take the very lowest gradient down which ice has been observed to flow, these would require that the Scandinavian ice should have been some miles in thickness. A similar difficulty meets us in attempting to explain the cause of movement of the ice in North America, which, on the supposition that this movement is due to gravitation, would require that its centres of dispersal should have been ten or twelve miles higher than the outer extremities of the mass. It is extravagant suppositions like these that have led many students of glacial geology to believe that these problems cannot be solved, and that have led not a few others to join the ranks of the diluvialists.

Is it not possible to find a simpler explanation of these facts regarding the uphill and extensive movements of land-ice? I venture to think that it is; and, indeed, it is one of the chief objects of this communication to put that explanation forward. In approaching that explanation, we must again digress a little, in order to consider some additional facts connected with the relation of Solar Energy to Ice.

First of these is the fact that ice expands with a rise of temperature, and contracts with a fall, more than any solid known. The change of dimensions referred to is more than three times that of iron, and ten times that of Carrara marble. It may be stated to be about half an inch per thousand feet for each degree of temperature.[1]

Next is the fact that ice is one of the most plastic of substances under pressure, and one of the most brittle under strain, so that while it can mould itself to all the ins and outs of the surface when pressure is applied, it yet gives way, snaps, and forms crevasses, directly any tension is put upon it. The plastic condition referred to probably arises from the fact that ice, like iron, wax, pitch, and some few other substances, does not pass abruptly from the solid to the fluid condition, but gradually softens when it is at temperatures very near the melting point. This latter state may be reached by an increase of pressure; for both Lord Kelvin

[1] *Geol. Mag.*, dec. iii., vol. viii. (1891), pp. 19-22.

and his brother, Professor J. Thomson, have shown that the melting point of ice is lowered 0°·0135 F. for each additional atmosphere of pressure, which is equivalent to the weight of a column of ice 37·7 feet in height.

Another factor in this connection is the important one that water in freezing expands to such an extent that 174 volumes of water become 184 volumes of ice, and that the force necessary to counteract that expansion is 1110 lbs. (about half a ton) per square inch of surface affected, for a fall of temperature of one degree Fahrenheit. So when water flows into a crevasse and freezes there, it is equivalent to driving in a wedge of the same dimensions as those of the crevasse, with a force equal to half a ton per square inch.

Lastly, but by no means the least important, is the fact, well-known to even the earlier students of glacial physics, that pure ice is nearly diathermanous to the solar rays of higher refrangibility.[1] These pass through sound and clean ice without sensibly raising its temperature, and the ice, like the air, is warmed, not so much by the direct rays of the Sun, as by radiation from other bodies which have been themselves previously warmed by that luminary. The meaning of this may be made clearer by reference to the fact that lenses of clean ice are sometimes used as burning-glasses, and that, in using them, the surface of the ice-lens farthest from the Sun and nearest the object heated, melts much faster than the corresponding surface facing the Sun. Most of the direct heat of the Sun goes through the ice without warming it; but the reflected heat returns with a different quality from what it had on entering, and endowed with a higher capacity for melting ice and snow. In this respect it will be seen that the solid and the fluid states of H_2O behave differently in relation to the Sun.

In experimenting with the lens of ice, it is important that one should bear in mind that the effect produced will vary materially with the initial character of the heat employed. Luminous heat from a source of great intensity produces less effect upon the side of the ice-lens facing the illuminant, than

[1] See especially W. D. Cooley, "Physical Geography," p. 76 (1876).

does dark heat emanating from a less-intense source. A large part of the heat from the more-intense source passes through the ice-lens; while, in the case of the heat of less-intense origin, nearly the whole of it is intercepted by the ice within the first eighth of an inch of the lens next the source of heat, and soon begins to melt it. The capacity for melting ice or snow, which most of the solar rays possess, is, therefore, inversely proportional to the refrangibility of these rays; or, what amounts to the same thing, that capacity is inversely proportional to the frequency of the ethereal undulations to which these heat rays are due.

One may further illustrate this important principle by reference to phenomena that may easily be studied on any sunny day after a fall of snow:—Near to any stone the snow melts, because of the heat radiated from the stone: far from that stone the snow, if clean, remains unmelted. Drop a twig, or a leaf, on to snow, or, better still, sprinkle a little dust on it, and in a few minutes the sunshine will cause these to radiate heat to the snow around, and thus to melt it. On the Swiss glaciers (as was illustrated by Dr Tempest Anderson's beautiful views when this paper was read) sand and small stones quickly melt the ice and snow around; and it is probably the action of the Sun upon the fine particles of rock blown on to the Alpine snows at high levels that brings about the conversion of this snow into *firn* or *nevè*. Dirty snow and ice melt quickly in sunshine, while clean snow and ice hardly melt at all. Around the well-known glacier tables so commonly seen on glaciers, phenomena due to the same principle may be seen. Sunshine falls on the stone "table" and warms it, but the heat does not readily pass downwards through the mass, if it is large, so the ice beneath it is *not* melted, except to a very small extent on the south side. But dark heat is abundantly radiated from the sides of the stone, and notably so from the side facing the midday Sun. Therefore much of the ice to the south of the stone is melted by radiant heat, less is melted on the east and the west, and least of all on the north. So the stone eventually comes to occupy a pedestal, whose position is in the northern focus of an elliptical depression, which has

been shaped entirely by heat radiated from the stone. The stone remains on the pedestal until the melting of the ice below its southern end causes it to topple off, when the whole process is begun anew.

Films of water lying upon ice heat up in the sunshine, and help materially to raise the temperature of the surface of the ice beneath and melt it, even though the thermal conductivity of water is only ·002. That of ice is ·0057 (or very nearly the general average of rocks). The specific heat of air is ·2669, and therefore the films of air whose presence gives rise to the white bands of glacier ice, cause these white bands to melt faster than the pure ice of the "blue bands," which are consequently left on the surface of a glacier as ridges, while the "white bands" sink into furrows, and are further deepened by receiving dust and fine particles of rock, as well as films of water.

The effect of radiated heat upon glacier ice is well shown by the marginal zone of depression, which occurs where the glacier meets the walls of its enclosing valley. Much of the convexity in the cross section of the surface of the glacier is due to this cause.

A little reflection over these generally well-known facts will lead us to see that something of much importance in the present connection can be made out of them. Let us take the case of a stone which, instead of remaining at the surface, has fallen into a crevasse that has subsequently been closed up by the onward movement of the ice past the place where the crevasse originated. The Sun's rays pass down through the overlying ice, impinge upon the surface of the stone, and straightway begin to warm it. Heat is now radiated from the stone, which, if it is a large one, will only radiate from the surface next the Sun, *i.e.*, from its upper surface. If the stone is dark coloured, it will probably both absorb, and radiate to the overlying ice, a large amount of heat, of that quality which is competent both to warm the ice itself and to melt it. Hydrostatic pressure squeezes the stone upward to take the place of the water, the melting proceeds, and, in course of time, the stone is back again at

the surface, where, sooner or later, it again tumbles into a crevasse, melts its way to the surface, and so on until the advance of the ice has carried it to the terminal moraine. This principle enables us to explain how it has happened that stones have so often been transported by ice to levels higher than that of their parent masses, often by many hundreds of feet, of which so many examples are to be found in Scotland and elsewhere. The extent to which a stone may be elevated by this cause is limited only by the thickness to which the enclosing ice attains. It is this cause which, during the Glacial Period, elevated organisms which had become enveloped in frozen mud, to positions often a thousand or more feet above that of their starting-point, and which has given rise to so firm a belief—still held by many whose opinions are entitled to respect—that there was a great submergence during the Glacial Period. I endeavoured to show, in a paper in the *Geological Magazine* for November 1874, that organisms could be elevated WITHIN the ice in this manner (not pushed before it, as careless or prejudiced writers have represented me to say), and subsequently left at these higher levels when the ice melted. It is this same property that stones in ice possess which has made fragments of coal, oil-shale, or other dark carbonaceous materials, melt their way up in the ice, and which, when the ice came to melt, contributed to their being sorted apart from other stones in the water-worn materials that form Eskers.

But this warming of stones within the ice produces a result of even greater importance. If heat be communicated to ice, the ice expands; and if the expansion arises from the heat radiated from a large number of stones, such as are known to exist in the lower parts of many glaciers—notably in those of Greenland and Alaska—this expansion must be a very important factor in propelling forward the part of the ice in which the stones occur. Furthermore, as I have pointed out in one of the communications above referred to, the heat that is constantly flowing outwards from the Earth itself enters the ice at all parts where the ice and the rock are in contact. There must necessarily ensue from the conjoined action of these two sources of heat a considerable amount of expansion.

And it is not difficult to see that in the case of a thick mass of ice whose upper surface is exposed to great cold, that the parts of such a mass of ice in contact with the rock will move past the rock at a rate which may well be equal to the average rate of flow at the surface. As this movement takes place under great pressure (each thousand feet of thickness of ice pressing on its rocky bed with a pressure equal to 25½ tons), the amount of erosion accomplished by a stone-shod mass such as this must be enormous. Little wonder that deep and wide grooves were gouged out of hard rock by the passage of land-ice over it, and little wonder, also, that old river-valleys were deepened into fiords, or were widened and deepened into lake-basins by the prolonged action of this same cause.

The effect of solar radiation upon stones that have become enveloped in ice is to co-operate with the onward movement, with "ablation and turgescence," and with the frontal resistance of the distal parts of the ice, in elevating the stones to the surface along a curve rising from the bottom of the ice upward and outward. In the case of streams of ice such as occurred here during the Glacial Period, the outward path of the included boulders was liable to many deflecting causes; but, on the whole, it may be said to have moved in the direction of least resistance, which may have pointed to a place very many miles away, where there was some local relief of pressure, brought about, perhaps, by melting, by the calving of icebergs, or by other causes.

The same cause which, though many miles away, influenced the course a boulder would take under ordinary conditions, came into operation in the cases where a glacial or other barrier was thrown across its path by an ice-stream. There are many instances of this kind, in North Britain especially, as, for example, that of the Galloway ice, which encountered the ice from the English Lake District upon the low ground of the Solway. The contest between the Scottish ice and the English, in this case, was a severe one, and ended in that from Galloway overmastering its English opponent, or, at any rate, in very materially influencing the course the conjoined streams were compelled to take. Another still more

marked case was that where the ice from the east of Scotland encountered the ice from Scandinavia. There can be no doubt that, near the climax of the Glacial Period, the ice originating within the mountains of Scandinavia did, for some time, extend far across the lowland area now occupied by the North Sea. This is shown not only by the occurrence of many boulders of undoubted Scandinavian origin in the glacial deposits of the North of England, but also by the strongly-marked deflection of the glacial markings on the eastern side of Scotland, as will be seen from a study of any good map of glacial markings, such as the one in James Geikie's "Great Ice Age," or in Sir Archibald Geikie's charming "Scenery of Scotland." It appears to me that the deflection referred to need not have been caused by ice of foreign origin which had actually reached that part, but may well have been produced by the action of an ice-barrier emanating from Scandinavia, and which met the Scottish ice somewhere to the east of our present coast, and then simply dammed the local ice back, so that it was compelled to move in directions contrary to what it would have taken if the barrier had not been there. It is to this damming-back by the ice from Scandinavia that I should be disposed to attribute the westward movement of the ice that lay to the east of the watershed in the North-West Highlands. Probably only the higher strata of the ice would so move. In the explanation of the origin of boulder clay by englacial means that I put forward in 1874,[1] the boulders and the materials of the boulder clay were assumed to have been transported *within*, and *not beneath*, the ice, and to have been left as a sediment when the ice melted. As this view has now met with general adoption, there ought to be no difficulty in explaining the westerly transportal of boulders in the present case.

The chief reason, however, why this glacial feature of the North-Western Highlands has been referred to is to emphasise the fact that, in order to produce such an effect as that noted, the Scandinavian ice need not after all have been so very

[1] *Geol. Mag.*, Nov. 1874, "On Drift."

thick. The ice in the North Sea area certainly must have had its upper surface at a higher level than that of the ice which passed over the watershed, but the difference in elevation need not have been anything like what it has been assumed to be. If, as is here maintained, the movement of glaciers is to a certain extent due partly to the effects of terrestrial radiation, partly to the effects of radiant heat emanating from the Sun, and comparatively little to gravitation, then it would follow that many of the difficulties that have hitherto confronted glacialists in attempting to explain the glacial phenomena of Eastern Britain will be cleared away, and we may turn our attention to other matters which are still under discussion.

It will therefore be seen from the foregoing statements that gravitation is by no means an essential factor in causing the movement of land-ice. Solar Energy, warming the stones within the lower parts of ice, and warming also the face of the rock next to it, co-operates with terrestrial radiation in elevating the temperature of the ice (more especially if it is thick) to a higher point at its base than it has at the surface. Differential expansion ensues; the parts of the ice in contact with the rock are warmed most, and, expanding most, are compelled to slide past the rock face, which they do regardless of both the superincumbent pressure and the enormous friction caused by the grinding of the stone-shod base of the ice over the rock beneath.

In speculating, therefore, upon the causes which impelled the land-ice of Scandinavia as one continuous stream, from its birthplace to the shores of Britain, we have no need to postulate the existence of land-ice miles in thickness at its starting-point. Solar Energy and terrestrial radiation, co-operating in the manner described, are quite sufficient to account for all the facts, even for the powerful deflection which the Scandinavian ice produced upon the streams of local origin, and even for that remarkable ponding-back of the ice of the North-Western Highlands, which made its upper layers cross the mountain tops, and carry boulders over the watershed westward towards the Atlantic.

XI. *Some Notes on a Rock allied to Limburgite, near North Berwick.* By J. G. Goodchild, Esq., F.G.S., F.Z.S.

(Read 20th April 1898; received for publication April 1899.)

The coast from the West Links at North Berwick eastward past Tantallon Castle has long been celebrated for the remarkably fine exposures of eruptive rocks which are there laid bare. There are beds of both trachytic and andesitic lavas at Kirkness and elsewhere; an almost endless variety of beds of tuff, showing every stage of gradation into rocks of sedimentary origin; one or more beds of geyserite; necks, intrusive sheets, and dykes of various kinds, from trachyte to limburgite—some of them remarkably fresh—are beautifully exhibited. There are also some examples of sand dykes, evidently due to the deposition of sand in cracks and fissures, formed, perhaps, as a result of earthquakes.

In the case of a group of rocks which, as a whole, are of so varied mineralogical composition, one would naturally expect to find examples of rocks of types which do not fit in very well with the currently-received petrographical classifications. Such, indeed, is the case here. These intermediate forms are of especial interest to those geologists who prefer to take a broad view of matters petrographical, because they very well illustrate the fact that Nature, in evolving the different varieties of eruptive rocks, has been, so to speak, careful not to weed out the forms that connect one type with another. There has been, in other words, no process of Natural Selection at work in this department of Inorganic Nature, so that a rock-species, strictly speaking, can hardly be said to exist. On the contrary, a perfect and complete chain of varieties can be traced which connect the most extreme types with each other by an infinite number of intermediate gradations.

A rock of this indefinite kind forms a rather conspicuous feature on the shore about midway between North Berwick and Tantallon Castle. One part of it is named the "Yellow Man" on the Ordnance Six-Inch Maps of the district. It occurs as a very irregular series of masses, which may be

regarded in the aggregate as a dyke, and which cut through, and harden, a mass of Lower Carboniferous tuff. The chief feature noticeable in the field, besides the irregularity referred to, is a laminated or platy structure, which runs parallel to the bounding surfaces of the mass, and which suggests the result of weathering upon a banding of alternate harder and softer zones, due originally to fluxion structure. There is a good figure of the mass in question given in Geikie's "Ancient Volcanoes of Great Britain," page 409, from a photograph by Mr Robert Lunn.

In hand specimens the rock is heavy, has a rusty surface where weathered, and shows a dark-coloured, close-grained, and compact ground mass, through which are scattered crystals, also of a dark colour, and with a very feeble lustre on their faces of fracture.

An examination of the rock under the microscope showed that it consisted of Olivine, Augite, and iron ores, set in a brownish, lithoidal paste, through which are scattered a few minute lath-shaped crystals of a plagioclase felspar, which appears to be Labradorite. On making a comparison of this rock with the Haddington Limburgites described by Dr Hatch, and with some typical specimens from the Kaiserstuhl, the resemblance was found to be very close, and were it not for the presence of the small quantity of minute felspars, the rock might be regarded as a true Limburgite. Its chief interest, however, lies in the fact that it clearly forms an intermediate link between an ultra-basic rock and the typical basalts which occur so abundantly as dykes and other intrusive masses in the immediate neighbourhood.

When this paper was read a scheme of classification of eruptive rocks was laid before the meeting, chiefly with the object of inviting a discussion as to how these intermediate lithological types of rock might be dealt with. The difficulty is greatly felt by those who have to do with the position of such rocks in museums where a wide range of lithological types is represented, and where those in charge wish as much as possible to simplify petrographical nomenclature, and to avoid the introduction of new names.

XII. *On the Maintenance of the Earth's Internal Heat.* By J. G. GOODCHILD, Esq., F.G.S., F.Z.S.

(Read 20th April 1898; received for publication April 1899.)

[ABSTRACT.]

The Earth is supposed by many physicists to be parting with its original heat at a rate which would seem to point to its consolidation having taken place within a few millions of years from the present time. On the other hand, the facts made known by geologists seem to require a very much longer period than the time referred to. It was pointed out that there are several causes in operation which tend to retard the assumed rate of cooling; while, on the other hand, there appear to be other causes which are giving rise to an evolution of heat within the Earth's crust, and which thereby help to maintain a high temperature at a variable distance below the surface. The general conclusion arrived at was that the Earth's internal heat is not entirely, or perhaps is not at all, a remnant of its original heat, or that which it had on consolidation; but that the heat in question is due largely to dynamic causes, partly aided also by surface-oxygenation, and by chemical reactions of various kinds both at and below the surface. The dynamic causes were regarded as referable to the effects of contractional crushing, and to the conversion of motion into heat in those cases where earth-creep is taking place. Some cases of earth-creep may arise through the unequal loading of the Earth's crust by the joint action of denudation and deposition; others may result from the subterranean transfer of rock-materials from one locality to another by plutonic action. These rocks may have been first softened by the transfusion of alkaline solutions, carried downward by osmosis from the floor of the ocean, and the material may then have been very slowly squeezed out along the ocean margins. Disturbances of equilibrium by such causes, and the consequent lateral flow of rock-material, must generate a certain amount of heat. Even luni-solar gravitational energy cannot rightly be left entirely out of account in such considerations as these, because it is quite

conceivable that slow terrestrial tides may be set up within the lithosphere under the conditions above referred to. It was further pointed out that the variability in the downward increment of heat observed when observations extending over a large area are compared, may be easily explained if the internal heat of the Earth is, even in part, due to one or other of these auxiliary causes.

XIII. *On the Occurrence of the Lesser Whitethroat* (Sylvia curruca) *in the Outer Hebrides, with Remarks on the Species as a Scottish Bird.* By WILLIAM EAGLE CLARKE, F.L.S., etc.

(Read 15th February 1899.)

Scottish specimens of the Lesser Whitethroat are *raræ aves.* The one exhibited at this meeting was obtained on the island of Barra, one of the southernmost of the Outer Hebrides, on the 24th of October last, and has been submitted to me for determination by its captor, Mr W. L. Macgillivray, a nephew of the distinguished ornithologist of that name.

This bird was shot on the west side of the island, and is the first known to have been obtained in, or about which we have any reliable information for, the Western Isles. That it was blown out of its course, or lost its way during its migration southwards, is the probable explanation of the appearance of this waif so far to the west; and in this connection it is of interest to remark that Mr Macgillivray sent along with it a Garden Warbler (*Sylvia hortensis*), captured on the same day — the second known occurrence of this species in the Outer Hebrides.

This Hebridean example of the Lesser Whitethroat is in adult plumage, and has been presented by Mr Macgillivray to the fine collection of British birds in the Museum of Science and Art, Edinburgh.

I desire to take this opportunity of calling attention to the very unsatisfactory statements made in all the modern standard works on British birds, to the effect that the Lesser

Whitethroat is a summer visitor to Scotland as far north as the Firth of Forth, Stirlingshire, and Argyllshire.

Before proceeding to discuss the bird's status as a Scottish species, it is desirable to recall the few records relating to this bird's occurrence in Scotland. These, so far as they are known to me, are given in chronological sequence below.

Seen at Musselburgh Haugh, near Edinburgh ; and in Ayrshire (Rennie's Edition of *Montague's Orn. Dict.*, p. 31, 1831).[1]

East Lothian, "breeding" in 1838 (Hepburn); Wallhouse, Linlithgowshire, male seen in May 1838 (Weir); Hamilton, Lanarkshire, "common" (Young); seen near Edinburgh (Macgillivray), (Macgillivray, *Brit. Birds*, ii. p. 358, 1838).

Linlithgowshire, nest and eggs found, June 13, 1839 (Weir). Nest and one of these eggs sent to Macgillivray (*op cit.*, iii. p. 729, 1840).

Unst, Shetland, 22nd September 1865, one; another, 23rd. "Observed it twice since." "Rarely met with" (Saxby, *Birds of Shetland*, p. 74, 1874).

"Very rare" in East Lothian (Turnbull, *Birds of East Lothian*, 1867).

Has been obtained in Argyllshire, and probably breeds near Loch Lomond (Gray), (More, *Ibis*, 1865, p. 25).

Sparingly met with in Dumbartonshire, and extends to Mid-Argyllshire (Gray, *Birds of the West of Scotland*, p. 95, 1871).[2]

Observed on 10th August 1880, at Traigh, South Morar, West Inverness-shire (Hamilton, *Zool.*, 1880, p. 503).

"I have only once been able to identify this species here" [Berwick-on-Tweed]. "Two were shot, one on the 14th, the other on the 26th September 1881" (G. Bolam, *Ann. Scot. Nat. Hist.*, 1897, p. 9).

One killed at Fyvie, Aberdeenshire, 4th November 1880; and another seen Mill of Tifty (G. Sim, of Gourdas, *Scot. Nat.*, vi. p. 13, 1881).

[1] In the following abstracts *additional information* only is quoted. Some of the authors repeat the statements of previous writers, and without acknowledgment.

[2] It is surprising that Gray contents himself with these mere statements concerning such a rare and interesting Scottish species, and especially so when treating of the Birds of the West of Scotland. The evidence was probably hearsay.

A summer visitor, but is seldom met with in the district (*A Guide to Loch Lomond and Neighbourhood:* "Birds," by James Lumsden, 1895).

One shot, North Ronaldshay, 18th September 1896 (A. Briggs, *Ann. Scot. Nat. Hist.*, 1897, p. 160).

In addition to this published information, I have been favoured with the following notes by my friend Mr William Evans:—

"During all the years that I have paid attention to the birds of the 'Forth' district of Scotland, I have never, except, perhaps, on one occasion, met with the Lesser Whitethroat; and no specimen, so far as I know, has ever been procured in this part of the country. The occasion referred to was on 15th May 1886, at the Temple end of Arniston Glen, when my attention was arrested by a bird which at the time I felt certain was a Lesser Whitethroat; but it was so shy that, try as I liked, I could not succeed in getting a *perfectly* satisfactory view of it. As a passing migrant I have no doubt the species occurs occasionally on the seaward portions of East Lothian and Fife; and, were a trained observer stationed at the Isle of May, it would almost certainly be detected there within a very few years. I very much doubt, however, if it is a summer visitor to any part of the district at the present day. From what Macgillivray wrote sixty years ago, it seems probable that a few pairs occasionally spent the summer in the Lothians at that time—indeed, his description of the nest and one of the eggs sent to him in June 1839 by Mr Durham Weir, from Linlithgowshire, together with Weir's own account of the birds and their nest ('British Birds,' vol. iii. pp. 729-731), leaves little room for doubt in the matter. As regards Mr A. Hepburn's East Lothian record, also given in Macgillivray's book, I may state that I had some correspondence with Mr Hepburn on the subject in March 1894, when he informed me that he observed the birds for two seasons only, viz., 1838 and 1839; that no specimen was obtained; and that Mr Weir told him in 1852 that he had never met with the birds in his neighbourhood after 1839. Mr Hepburn, it may be added, left

East Lothian in 1855, and died at Aldridge, near Walsall, Staffordshire, only last August."

Mr Service tells me that it is a rare summer visitor to Dumfriesshire, and that he has found two nests in that county, but that the bird is seldom met with in Kirkcudbrightshire.

In arriving at the summarised conclusions given below, I have carefully considered the evidence that is afforded by these original sources of information. I consider that a small proportion only of what has been recorded is really satisfactory and will stand the test of a searching examination from all standpoints. Some of the records are bare statements, unaccompanied by details or other testimony in support of their accuracy. Others are based upon evidence of the very slightest nature, and are only to be regarded as possibilities rather than probabilities. Others, again, are undoubtedly cases of erroneous identification, the common species of Whitethroat having been mistaken for the rarer. Most of the statements, good, bad, and indifferent, have been reproduced again and again in the literature quoted—though not reproduced here—and in general works on British birds, until they have come, by sheer force of reiteration, to be regarded as established facts.

To sum up, the following are the conclusions I have arrived at concerning the Lesser Whitethroat as a Scottish bird:—

(1) It cannot be regarded as a summer visitor to south-eastern Scotland, sixty years having elapsed since the two reputed and only instances of the bird's breeding in the area were recorded. Since that date we have no positive evidence of its occurrence during the summer. (2) The species occurs sparingly along the eastern seaboard and its vicinity as a bird of passage,[1] specimens having been obtained at intervals in the autumn (when collectors are on the alert) between Unst, the northern isle of Shetland, and Berwick-on-Tweed. It is during the migratory period *alone* that specimens have been obtained. (3) It is a rare and extremely local summer

[1] The Lesser Whitethroat is a summer visitor to central and southern Scandinavia.

visitor to south-western Scotland, occurring only as far north as Ayrshire. (4) It is a rare casual visitor to the west coast north of the Clyde, probably only as a waif during the migratory period.[1]

XIV. *On the Occurrence of the Asiatic Houbara* (Houbara macqueenii, *Gray and Hardwicke*) *in Scotland.* By WM. EAGLE CLARKE, F.L.S., etc.

(Read 15th February 1899.)

The Asiatic Houbara, or Macqueen's Bustard, is a new and interesting addition to the fauna of northern Britain. We have to thank Mr J. G. Walker, the owner and captor of the bird, for allowing this first Scottish specimen to be exhibited at the meeting of the Royal Physical Society this evening.

On the 24th of October last, when partridge shooting at St Fergus—part of the Pitfour estate, in Aberdeenshire—Mr Walker obtained this bird, which was at the time thought to be a Little Bustard (*Otis tetrax*). When first seen it was in a turnip field. It got up out of range, and flew slowly, as if wounded. The bird was pursued and eventually secured. On being skinned, a swan shot was found embedded in its thigh.

Some doubt having arisen as to the identity of this bird, Mr Walker submitted the specimen to me for determination, and I have pleasure in confirming that gentleman's surmise that the bird is undoubtedly an example of *Houbara macqueenii.* It is a young female, but whether about four months or sixteen months old is, perhaps, questionable, since, as in many other cases, nothing appears to be on record concerning the stages through which this species passes ere full plumage is assumed, or even the age at which the plumes of adolescence give place to those of maturity. The specimen under consideration, however, has a slight

[1] As bearing upon this bird's status in Scotland, it may be well to state that the species is scarce in the counties of Durham, Westmoreland, and Cumberland.

crest, a moderately developed ruff on the sides of the neck, and some show of bluish-grey on the sides of the chest.

It is the fourth British example of an Eastern species, which, as its name implies, is not even a native of Europe—its nearest haunts being in Persia, whence it spreads eastwards through the Aralo-Caspian region and Beluchistan to Northern and Western India. This fine Bustard is thus a remarkable example of those erratic wanderers, not a few of which, from time to time, appear in Britain, chiefly in the autumn months.

It is worthy of note that all the specimens of this Houbara which have been known to visit our shores have been obtained in the vicinity of the East Coast, and all of them in the month of October.

The following are the previous British records:—

One (presumably a female, from the dimensions given), Kirton Lindsay, Lincolnshire, obtained on 7th October 1847 (*Zoologist*, 1848, pp. 1969, 2065, 2146). First recorded as a Little Bustard.

A male, Marske, north-east coast of Yorkshire, 5th October 1892 (*Zoologist*, 1893, p. 21).

A young male, near Spurn Head, Yorkshire coast, 17th October 1896 (*Zoologist*, 1896, p. 433). I had the pleasure of seeing this specimen, both on the wing and while feeding, just before it was obtained.

The Asiatic Houbara has occurred in several European countries, but everywhere as a rare and accidental visitor. There is no evidence that it is a migratory species, unless, indeed, its visits to Northern India, in the winter, from adjoining regions can be regarded as affording evidence of the migratory habit.

It is somewhat remarkable that the only other member of the genus, the African Houbara (*H. undulata*), which inhabits Northern Africa and the Canary Islands, thus occurring as near to us as Algeria, has not yet been known to visit our islands, though it occasionally crosses the Mediterranean, to appear as a wanderer in the countries of Southern Europe.

XV. *On the White Phase of Plumage in the Iceland Gull* (Larus leucopterus, *Faber*). By Wm. Eagle Clarke, F.L.S., etc.

(Read 19th April 1899.)

The specimen of the Iceland Gull upon which this communication is based was shot in Kirkwall Bay, Orkney, on the 20th of April 1893. It was formerly in the collection of the late Mr Thomas M'Crie, of Kirkwall, but was recently acquired for the Edinburgh Museum of Science and Art.

Before alluding to the special peculiarities of this specimen, it may be well to remark upon the general resemblance borne by the Iceland Gull to another species, namely, the Glaucous Gull (*Larus glaucus*). These two birds stand in much the same relation to each other, as regards plumage, as do the familiar Lesser and Greater Black-backed Gulls (*Larus fuscus* and *L. marinus*). The Iceland species is the smaller bird, and possesses proportionately longer wings than its congener. It is also much the rarer bird of the two everywhere, and is only an irregular visitor to Britain, while the Glaucous Gull is an annual winter visitant.

Notwithstanding the fact that the Iceland Gull was described by Faber ("Prodromus Isländischen Ornithologie," p. 91) as long ago as 1822,[1] there is good reason to believe that until to-night one important stage in the history of its various plumages, namely, the penultimate or white stage, has remained undescribed. In support of this statement, I

[1] This species was first discovered, however, in the year 1818, during Captain John (afterwards Sir John) Ross's voyage of discovery in Davis Strait and Baffin's Bay. Captain Sabine, R.A., F.R.S., who accompanied the expedition as zoologist, etc., published on his return "A Memoir on the Birds of Greenland" (*Trans. Linn. Soc.*, xii. pp. 527-559, 1819), a contribution based chiefly upon the collection made during the voyage. Herein he described (pp. 546-47) this bird, by the advice of Temminck, whom he consulted, as an undescribed Arctic race of the Herring Gull (*Larus argentatus*), though he personally was inclined to regard it as a species new to science.—The reference to Sir James C. Ross's first voyage made in "Yarrell's British Birds," ed. 4, iii. p. 648, in connection with bird, is a mistake. It should be to Sir John Ross's first voyage.

may quote Mr Howard Saunders, the recognised authority on the order Gaviæ (Gulls, Terns, and Skuas). Writing in 1896 in his monograph of that order ("Brit. Mus. Cat. Birds," xxv. p. 296), he states "that the young and immature of the Iceland Gull resemble those of the Glaucous Gull, *except as regards the white phase, of which I have no certain knowledge, though it probably exists*" (the italics are mine). Writing to me under date of the 31st of March of the present year, Mr Saunders, in reply to my inquiries as to whether these remarks still held good, says: "I am not certain, at the moment, if the Iceland Gull has been actually *proved* to go through the same white phase as *L. glaucus*, though there was strong probability that this would be the case; and the Museum is to be congratulated on the acquisition."

Although it is desirable to emulate the admirable caution displayed by Mr Saunders in the reply quoted, I think it may be fairly assumed that the specimen under consideration actually supplies the stage so long unknown in the plumage of the Iceland Gull, and replaces by demonstration the reasonings of deduction.

In the plumage of the first year (I quote largely from Mr Saunders, *op cit.*, p. 293, for the earlier and adult plumages) the upper and under surfaces are streaked and mottled with ash-brown on a paler ground colour; the feathers of the mantle are margined with buffish-white, which produces a creamy appearance; outer quills clay-brown on the outer webs and paler on the inner webs; upper and under tail-coverts rather boldly marked with brown; rectrices, on the contrary, rather finely mottled; bill ochre-yellow at the angle, thence blackish to the tip; tarsi and toes brownish.

In its second year (that is, after the next autumn moult) both upper and under surfaces are much lighter, and pale grey feathers begin to show on the mantle, the outer primaries being all but white.

We now come to the plumage which has hitherto remained undescribed, namely, that of the third year. The mottlings on the upper surface gradually disappear, and for a short time the bird wears a white dress. The specimen exhibited

is pure white, except (1) a few creamy feathers, with irregular bars of pale greyish-brown, on the scapulars; (2) that the lower breast and abdomen are washed with pale umber, the feathers of the latter being edged with white, producing a mottled appearance; and (3) that the under tail-coverts are barred with pale umber. Indeed, so white is this example, that, when viewed from the distance of a few feet only, the vestiges of its previous garb are not apparent. The apical third of the bill is blackish, as in the previous stages.

At the subsequent moult, or during the fourth year, the bird arrives at maturity. A pearl-grey mantle is assumed; the secondaries are tipped with white, forming a band that contrasts with the grey; the bill becomes yellow, with a red patch at the angle of the lower mandible; the rest of the plumage pure white, except in winter, when the head and neck, as in other members of its genus, become streaked and mottled with pale brown.

In this Orcadian specimen the wing measures 15 inches, the culmen 1·62 inch, and the tarsus 2·07 inches.

That examples in the white stage of plumage have remained so long unknown may probably be explained by the following facts:—(*First*) Because this phase of plumage is only worn for a few months during the third year of the bird's existence. (*Second*) The species is far from abundant. This is due in some measure, perhaps, to its habitat being remarkably circumscribed, since the bird is confined in summer to the island of Jan Mayen, Greenland, and, possibly, the American side of Baffin's Bay. (*Third*) Because the older individuals, including the white birds, do not, as a rule, wander far from their Arctic haunts, their regular winter range extending to Iceland, the Faroes, and Scandinavia. It is almost entirely the young birds that roam irregularly to the British seas, and on rare occasions as far as the Bay of Biscay, and on the American side of the Atlantic to the coast of Massachusetts.

When speaking on this species before the Royal Physical Society, it is interesting to recall the fact that on the 8th of March 1823, Mr Laurence Edmonston communicated to

the Wernerian Society the first occurrence of this bird in Britain, describing as a new species, under the name *Larus islandicus*, or Lesser Iceland Gull, specimens obtained in Shetland (*Mem. Wern. Soc.*, iv. p. 506). Mr Edmonston's name, however, is one year younger than that of Faber.

In connection with the distribution of the Iceland and other Arctic Gulls, it would be interesting to know what species was found breeding at one of the North Georgian (Parry) Islands, and referred by Sabine to his Arctic race of the Herring Gull (*Larus argentatus*) (see footnote, p. 164). A year after accompanying Captain John Ross to Davis Strait, Sabine sailed under Parry, in the capacity, among others, of zoologist, on that distinguished explorer's first North-West Expedition, and published in the Appendix to that voyage, in 1824, an account of the mammals and birds observed in the regions visited. At page cciv. of this Appendix, Sabine, who, as we have seen, really discovered the Iceland Gull one year, or, perhaps, two years before, tells us that both the Greenland variety of the Herring Gull (=the Iceland Gull), without the black marking on the primary quills, and one individual of the common form of Herring Gull, were observed on one of the North Georgian Islands, where a number of the former had their nests on a cliff. I have been unable to trace this record in the synonymy and copious references to literature quoted by Mr Howard Saunders in his standard monograph of the Gaviæ ("Brit. Mus. Cat. Birds," 1896); though from the days of Richardson and Swainson in 1831 ("Fauna Boreali Americana," Birds, p. 418), down to the present decade, it has been included in the synonymy of, or regarded as the Iceland Gull in all important ornithological works.

XVI. *Additional Records of Spiders and other Arachnids from the Edinburgh District.* (Second Instalment.) By GEORGE H. CARPENTER, B.Sc., and WILLIAM EVANS, F.R.S.E.

(Read 18th January 1899.)

I. ARANEIDEA (*SPIDERS*).

In April 1896 we laid before the Society a first instalment of additions to our list of the Spiders of the Edinburgh District, which was afterwards published in the *Proceedings*, Vol. XIII. pp. 308-315. We now submit a second supplement, containing records of eleven further additions, which brings the total number of species at present known to occur in the district up to 190.[1] Six of the eleven—namely, *Prosthesima electa* (C. L. K.), *Microneta rurestris* (C. L. K.), *Entelecara trifrons* (Cb.), *Diplocephalus speciosus* (Cb.), *Tapinocyba subitanea* (Cb.), and *Pachygnatha listeri*, Sund. —are not only additions to the Edinburgh list, but to the Scottish list as well. One of the remaining five is the large, beautifully-marked *Epeira quadrata* (Clk.), a species we are the more pleased to be able to include, seeing we drew attention to its absence from the original list.

Fresh localities for some of the rarer species already on the list have also been discovered, and of these, with a few others of county interest, we likewise submit a memorandum. Perhaps the most interesting record in this section is that relating to *Prosopotheca monoceros* (Wid.), the female of which had not previously been obtained in the British Isles.

During the four and a half years that have elapsed since the publication of our main list (*Proceedings*, Vol. XII. pp. 527-590), proposed changes in nomenclature and arrangement have assuredly not been wanting. Beyond giving effect to a few necessary alterations, chiefly in specific names, we do not, however, propose to depart at present from the lines followed in drawing up the original list.

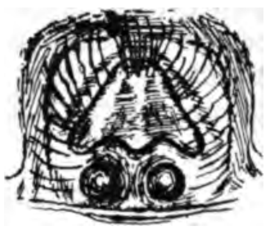
[1] The discovery of *Entelecara thorellii* since the above was written raises the total to 191. No doubt the number of additions might have been greater, but for some time past other groups have been occupying my attention, to the comparative exclusion of the Spiders.—W. E.

LIST OF ADDITIONAL SPECIES.

Prosthesima electa (C. L. K.).

Drassus pumilus, Bl. Spid. Gt. Brit. and Irel.

A single example (a female) of this rare spider was captured on 10th June 1897, while running in the sunshine on a bare sandy spot on Largo Links, coast of Fife. The Rev. O. P. Cambridge, to whom we are indebted for the identification of this specimen, informs us that it differs greatly in its colours from the normal types, the cephalothorax and tarsi being yellowish-brown, in place of red-brown; the femora rather paler yellow-brown, in place of yellow-red; and the genuæ and tibiæ deep brown, in place of black-brown. In England the species has apparently occurred only in Lancashire and Norfolk, and the present is the only Scottish record. The genital aperture, of which (magnified) we give a figure, is of a very distinct and characteristic form.



Asagena phalerata (Panz.).

Theridion signatum, Bl. Spid. Gt. Brit. and Irel.

An immature example of this well-marked species was obtained at Innerleithen, Peeblesshire, in January 1897. An adult female was taken near Oldcambus, in Berwickshire, by Hardy many years ago. The only other Scottish locality known to us for the species is Aviemore, Inverness-shire, where it was common in May and June 1893 (Evans—see *Annals Scot. Nat. Hist.*, 1894, p. 230).

Microneta rurestris (C. L. K.).

Neriene flavipes, Bl. Spid. Gt. Brit. and Irel.
Neriene fuscipalpis (in part), Cambr. Spid. Dorset.

Since the publication of our list, it has become clear to us that two species are included under the name *Neriene*

fuscipalpis in Cambridge's "Spiders of Dorset," and therefore probably also in our list, namely, *Microneta rurestris* (C. L. K.) = *Neriene flavipes*, Bl.; and *M. fuscipalpis* (C. L. K.) = *N. gracilis*, Bl. In the latter, the femur of the palp is quite black, and it has a differently-formed lamella to the bulb. Having only lately learnt to distinguish these two forms, we have not yet had time to re-examine our earlier specimens. Recent captures, however, prove that both are present in this district. A typical example (an adult male) of *M. rurestris*, which would appear to be the rarer of the two here, was got on a wall at Comiston, near Edinburgh, 10th October 1898; while adult males of *M. fuscipalpis* occurred at Carribber (Linlithgowshire) in February 1898, Blackford Hill in March, Edgelaw, near Rosslyn, in October, and Torphin (Pentlands) in November.

Entelecara thorellii (Westr.).

Walckenaëra fastigata, Bl. Spid. Gt. Brit. and Irel.
Walckenaëra thorellii, Cambr. Spid. Dorset.

Since these notes were drawn up, we have (July 1899) obtained an adult male of this very rare Spider on Bavelaw Moss, a few miles south-west of Edinburgh. Mr Cambridge, to whom we have given this specimen, found the only other example known to have been got in Great Britain, near Southport, in Lancashire, in June 1859. In Ireland, a pair were taken at Portmarnock, Co. Dublin, in May 1895, as recorded in Carpenter's list of Irish Spiders. Abroad, the species has occurred in France, Germany, and Sweden.

Entelecara trifrons (Cb.).

Walckenaëra trifrons, Cambr. Spid. Dorset.

An adult male of this scarce little spider was captured near Colinton (Midlothian) in July 1897, and furnishes the first record for Scotland. It occurs locally in England and Ireland, and has been recorded from Northern France and from as far off as Kamtschatka.

Diplocephalus speciosus (Cb.).

Plæsiocrærus speciosus, Cambr. Proc. Dorset Field Club, vol. xvi., 1895, p. 109.

A single adult male of this minute and little-known species was got among damp moss by the side of Bonaly Burn, Pentland Hills, on 28th April 1898. The type specimen—the only other one as yet recorded from Great Britain—was taken at Bloxworth, Dorset; in Ireland, however, where it seems to be widespread, it has occurred in several counties (see Carpenter's "Spiders of Ireland," *Proc. Roy. Irish Acad.*, 3rd ser., vol. v., 1898). There is no doubt that the genera *Diplocephalus* and *Plæsiocrærus* should be united, and the former name being the older must be adopted.

Diplocephalus latifrons (Cb.).

Walckenaëra latifrons, Cambr. Spid. Dorset.

A pair (ad. ♂ and ♀) of this form, which, though scarce, seems to have a wide range in Europe (West of Ireland to Northumberland and Dorset; Denmark and France to Hungary), were found under a piece of wood lying on dead leaves at Mortonhall, near Edinburgh, April 1898. The only other Scottish record is from Renfrewshire (Morris Young, *Annals Scot. Nat. Hist.*, 1894, p. 185).

Diplocephalus beckii (Cb.).

Walckenaëra beckii, Cambr. Spid. Dorset.
Plæsiocrærus beckii, Simon, Arachn. France.

The Rev. O. P. Cambridge has detected, among a number of small spiders which we recently sent to him from the neighbourhood of Edinburgh, an adult male of this rare species. It was got in October 1896—we believe among moss, on Corstorphine Hill. Its recorded occurrences in Britain are very few — Dorset, near London, and near Dunkeld (Prof. Trail).

Tapinocyba subitanea (Cb.).

Walckenaëra subitanea, Cambr. Spid. Dorset.

We refer to this form, a very minute adult male spider found in moss taken off a wall by the roadside at Morton, three miles south of Edinburgh, on 5th November 1897. The only other British records for it appear to be from Dorset and near Carlisle.

Pachygnatha listeri, Sund.

This rather pretty spider was obtained in abundance (ad. ♂s and ♀s) off long grass and other herbage on a bank by the roadside at Rosslynlee Railway Station, 20th October 1897. We find we have also a female taken at Dreghorn in July 1894, and another at Morton in April 1898. Though not common, it is apparently widespread in England, and occurs also in Ireland, but has not been recorded from Scotland till now.

Tetragnatha extensa (L.).

As explained in our previous Supplement, all the specimens recorded in our Edinburgh list under the name of *Tetragnatha extensa* belong, according to Mr Fred. O. P. Cambridge's recent paper on the genus, to the form which Scopoli named *T. solandrii.* We are now able to restore *T. extensa* to the list, an adult male and many half-grown examples of the typical form, which is very widely distributed both in Great Britain and in Ireland, having been found on heather in a small peat-bog on the Pentland Hills above Currie, in October 1897. Several immature specimens were also taken on Bavelaw Moss, a few miles farther west, in April 1898.

Epeira quadrata (Clk.).

We are pleased to find that this fine spider, though decidedly local, is not altogether absent from the district. In October 1897, several adult females and many young

examples were found on rushes in a damp hollow on the Pentland Hills, near Bavelaw Castle. During the same month a few more were beaten out of heather in two other localities on the Pentlands, namely, at Loganlee and Craigenterrie. Occurs also on the Ochils above Milnathort.

ALTERATIONS IN NAMES.

Dysdera crocota, C. L. K.

Dysdera rubicunda, Blackwall's Spid. Gt. Brit. and Irel.
Dysdera cambridgii, Carpenter and Evans' List Spid. Edin., p. 535.

There can now be little or no doubt that the two ♀ *Dysderæ*, somewhat doubtfully recorded in our list as *D. cambridgii*, Thor., and another since obtained in a house at North Berwick, in August 1897, belong to the other British form, *D. crocota*, C. L. K. We have been led to reconsider our former decision by the discovery of a colony of the latter species, from which both sexes were got, at Eyemouth, on the coast of Berwickshire, in September 1895 (Evans, *Proc. Berw. Nat. Club*, xv. p. 118), thus giving to it a much more northern range in Britain than the other. The three specimens referred to have, as the Rev. O. P. Cambridge, to whom they have been submitted, points out, on the upper side of the posterior extremity of the femora of the fourth pair of legs, the one or two small spines which are said to be almost always present in *crocota*, but never in *cambridgii*. The latter name must therefore be deleted from our list and the former substituted.

Typhocrestus dorsuosus (Cb.).

Erigone dorsuosa, Cambr. Proc. Zool. Soc. Lond., 1875, p. 196.
Typhocrestus digitatus, Cambr. Ann. Scot. Nat. Hist., 1894, p. 19 (*non* P. Z. S., 1872, p. 758); and Carpenter and Evans' List Spid. Edin., p. 571, and Supplement I., p. 314.

Mr Cambridge informs us that, after a careful comparsion of the types, he has satisfied himself that our Scotch spider, identified for us and described by him (*loc. cit.*) as *Typhocrestus digitatus*, is not the same as his Continental spider of that name, but is identical with his *T. dorsuosus*. The two forms are evidently very closely related, and may not, after all, be

specifically distinct. For the present, however, our spider must be called *dorsuosus* and not *digitatus*. On the Continent, *T. dorsuosus* has occurred in Southern France and in Holland, and Carpenter has recently recorded it from Ireland.

ADDITIONAL LOCALITIES FOR SPECIES ALREADY ON THE LIST.

Harpactes hombergii (Scop.).—Canty Bay (East Lothian), December 1895, ♀.

Segestria senoculata (L.).—Linlithgow, March 1898.

Oonops pulcher, Templ.—North Berwick Law, January 1896; Binny Craig (Linlithgowshire), March 1898.

Drassus cupreus, Bl.—Binny Craig, March 1898.

Clubiona reclusa, Cb.—In July 1897 adults of *both* sexes were common in rolled-up leaves of *Alchemilla vulgaris*, at Greenbank, near Edinburgh; Uphall (Linlithgow), September 1896, ♀.

Clubiona brevipes, Bl.—An ad. ♀, recently identified for us by Mr Cambridge, was got off furze on the Braid Hills, in April 1893.

Zora spinimana (Sund.).—Banks of the Esk, near Rosslyn, October 1897; Arniston, May 1898; Lindores (Fife), December 1898 (R. Godfrey).

Cryphœca sylvicola (C. L. K.).—Carribber (Linlithgow), February 1898, one.

Hahnia elegans (Bl.).—In *Sphagnum* on Bavelaw Moss (Midlothian), March 1899, one ad. ♀ and several immature.

Ero furcata (Vill.).—North Berwick Law, January 1896.

Nesticus cellulanus (Clk.).—Manuel (Stirlingshire), March 1898; Moredun, near Edinburgh, in disused underground limestone-quarry, April 1899, ♀.

Theridion lineatum (Clk.).—Philipstoun (Linlithgow), October 1896, a few; Linlithgow, August, common.

Theridion denticulatum, Walck.—Adults of both sexes, and immature examples, common under loose stones on a wall close to Kinross, May 1898.

Theridion pallens, Bl.—Common on bushes in Arniston *Grounds* (Midlothian), June 1898.

Pholcomma gibbum (Westr.).—North Berwick Law (East Lothian), January 1896, two ♂s.

Pedanostethus neglectus (Cb.).—Polton Woods (Midlothian), among dead leaves, April 1898, an ad. ♂.

Bolyphantes alticeps (Sund.). — Harburn (Midlothian), October 1895, ad. ♂; Uphall (Linlithgow), September 1896, ad. ♂.

Drapetisca socialis (Sund.).—Tyninghame Woods, common on gates, September 1894; Falkland Woods, August 1895, a few immature; fir wood, near Midcalder, October 1897, ♀.

Linyphia insignis, Bl.—Ad. ♂s common under stones at foot of North Berwick Law, 2nd January 1896; Philipstoun, October.

Linyphia clathrata, Sund.—Philipstoun, October 1896.

Leptyphantes minutus (Bl.).—Uphall, September 1896, ♀.

Leptyphantes obscurus (Bl.).—Three ad. ♂s and two ♀s, near Craigenterrie, Pentland Hills, October 1897.

Leptyphantes blackwallii, Kulcz.—Uphall, September 1896, ♂ and ♀.

Leptyphantes ericæus (Bl.).—North Berwick Law, January 1896, ad. ♂.

Bathyphantes concolor (Wid.).—Near Linlithgow, February 1898.

Bathyphantes nigrinus (Westr.).—Carlowrie (Linlithgowshire), March 1898, two ♀s; Arniston, June, ♂.

Bathyphantes dorsalis (Wid.).—Banks of the Avon (Linlithgow), June 1895.

Porrhomma egeria, Sim.—In April 1899, an ad. ♀ was taken in an old limestone mine, at Moredun Mains, near Edinburgh.

Porrhomma pygmæum (Bl.).—Banks of Avon above Linlithgow, February 1898, ad. ♂.

Tmeticus abnormis (Bl.).—Near Balerno, an ad. ♀, and south bank of the Esk at Rosslyn, ad. ♂, October 1897; banks of the Avon, below Crawhill, ♀, July.

Tmeticus rufus (Wid.).—Corstorphine Hill, October 1896, ad. ♂ and ♀; Vogrie Glen (Midlothian), February 1897, ad. ♀; banks of the Avon, near Linlithgow, ♀, July.

Tmeticus reprobus (Cb.).—North Queensferry (Fife), November 1896, ad. ♂ and ♀ ; adults of both sexes common under stones at high-water mark, Gosford Bay (East Lothian), October 1897.

Tmeticus huthwaitii (Cb.).—Ad. ♀ under a clod on the banks of the Almond at Carlowrie, March 1898.

Tmeticus bicolor, var. *concinnus*, Thor.—Among a number of ordinary *T. bicolor* taken off a paling at Balerno in October 1897, there is an adult male of this small form. By some authorities it is regarded as a distinct species, but we scarcely think it should be ranked so high.

Tmeticus prudens (Cb.).—An ad. ♂, Dirleton Common (East Lothian), 16th January 1897.

Microneta viaria (Bl.).—Braid Hills, March and April 1893, ten (♂s and ♀s); Kirknewton, April 1895, ad. ♂ ; North Berwick Law, several ♂s and ♀s, January 1896; Ravelrig, October 1896, ad. ♂; Carribber (Linlithgow), February 1898, ♂.

Sintula diluta (Cb.).—An ad. ♀ among *Sphagnum* on Bavelaw Moss (Midlothian), March 1899. Identified by Mr Cambridge.

Gongylidium fuscum (Bl.).—Three ad. ♂s, Luffness Links, September 1896, and another, July 1898.

Gongylidium agreste (Bl.).—Ad. ♂, Ravelrig, October 1896, and another on a fence at Balerno, October 1897.

Tiso vagans (Bl.).—Ad. ♂ and ♀ under stone on the Pentlands above Dreghorn, October 1897.

Erigone dentipalpis (Wid.).—Near Torphichen, July 1895, ad. ♂.

Erigone longipalpis (Sund.).—North Berwick Links, January 1896, several ad. ♂s.

Neriene (Gonatium) rubens, Bl.—North Berwick, January; Uphall, September, ♀ ; Philipstoun, October 1896.

Neriene (Gonatium) rubellum, Bl.—Penicuik Glen, October 1896, ad. ♀ ; Rosslyn, October 1897, ad. ♂.

Gonatium bituberculatum (Wid.).—Several adults of both sexes, Lochgelly (Fife), May 1895; near North Berwick, January 1896, imm. ♀.

Dismodicus bifrons (Bl.).—Arniston, June 1898, ad. ♂.

Savignia frontata, Bl.—Abercorn (Linlithgow), October 1896.

Araeoncus crassiceps (Westr.). — Adult and immature examples of both sexes common among sand and flood refuse on the south shore of Loch Leven, 14th May 1898.

Lophocarenum parallelum (Bl.).—Dirleton Links, August 1897, ad. ♂ ; adults of both sexes fairly common under stones and pieces of wood in an old pasture at Edgelaw, Midlothian, 8th October 1898.

Lophocarenum nemorale (Bl.). — Ravelrig, among leaves, four ad. ♂s and two ♀s, October, and Torphin Hill, Pentlands, ♂, November 1896.

Diplocephalus cristatus (Bl.).—Banks of the Avon, near Linlithgow, July, ♂.

Diplocephalus (*Plæsiocræerus*) *permixtus* (Cb.).—Ravelrig, October 1896, ♂ ; Boghall Glen, Pentlands, October 1897, ♂ ; Hallyards, near Ratho, March 1898, ad. ♂.

Diplocephalus (*Plæsiocræerus*) *fuscipes* (Bl.). — Harburn (Midlothian), October 1895, adults of both sexes; Penicuik Glen, October 1896, ad. ♂s and ♀s; Lundin Wood, near Dunfermline, October 1897, ♂ ; near Ratho and Linlithgow, March 1898, ♂s.

Diplocephalus (*Plæsiocræerus*) *alpinus* (Cb.).—Braid Hills, March 1893, ad. ♂; Corstorphine Hill, October 1896, two ♂s; Dreghorn, March 1897, ♂ ; Blackford Hill, February 1898, ♂ ; Bush, near Rosslyn, March 1899, several ♂s; Mortonhall Woods, under pieces of wood, April and May 1899, adults of *both* sexes fairly common.

Walckenaëra acuminata, Bl.—Lochgelly, May 1895, ad. ♀; North Berwick, January 1896, ad. ♀; Rosslyn Glen, October 1896, ad. ♂ ; Dollar, April 1897, ad. ♀.

Prosopotheca monoceros (Wid.).—A pair (ad. ♂ and ♀) were got on Dirleton Common, East Lothian, in January 1897 The female of this rare little spider has been described by M. Simon, from France, but the present appears to be the first record of its detection in the British Isles.

Maso sundevallii (Westr.).—Braid Hills, March 1893, ad. ♀. Verified by Mr Cambridge.

Pachygnatha clerckii, Sund.—Ormiston (East Lothian), July 1895, ad. ♀ ; near North Berwick, January 1896, ♀;

Philipstoun and Abercorn (Linlithgow), October; near Manuel (Stirlingshire), March 1898, several adults.

Zilla x-notata (Clk.).—Haddington, on walls, ♂s and ♀s common, September 1896; North Berwick, August 1897; Linlithgow, several, one ♂ ad., August.

Epeira cucurbitina (Clk.).—Three ad. ♂s off grass, Heriot (Midlothian), June 1898; Gosford Links, ad. ♂ off grass, June.

Epeira diademata (Clk.).—Near Torphichen, August 1895.

Oxyptila trux (Bl.).—Comiston, July 1896, ♀ beside her cocoon containing about fifty eggs; Luffness Links, July 1898, ad. ♂.

Trochosa picta (Hahn).—Shore between Port Seton and Longniddry, August 1898, a few.

Trochosa ruricola (De G.).—Morrison's Haven, west of Prestonpans, October 1898, several ad. ♀s.

Trochosa terricola, Thor.—Selms Moor, Midcalder, May 1895, ad. ♂; near Linlithgow, July, ♀; Lomond Hills, August, ad. ♀.

Lycosa nigriceps, Thor.—Banks of the Avon (Linlithgow), June 1895.

Epiblemum scenicum (Clk.).—Linlithgow, August.

Neon reticulatus (Bl.).—Binny Craig (Linlithgowshire), 12th March 1898, ♀ scarcely mature.

II. PHALANGIDEA.

ADDITIONAL SPECIES.

We have two species to add to the list of Phalangids or "Harvestmen" recorded for the Edinburgh district, thus bringing the number up to sixteen.

Oligolophus hansenii (Kraep.).

In our list of *Phalangidea* published in 1895 (*Proc. Roy. Phys. Soc.*, Vol. XIII. pp. 114-122), two forms were recorded under the name *Oligolophus tridens*, namely, the true *O. tridens* of Koch (which is common among grass and rushes in moist

places), and a closely allied darker Phalangid obtained on bushes and walls. In 1896 specimens of this latter form were sent to Professor Kraepelin, of Hamburg, who at first named them *O. ephippiger*, Sim. (=*agrestis*, Meade), but afterwards coincided with Mr Cambridge (to whom one of the specimens had in the meantime been shown) as to their distinctness from that, and described them and other similar specimens obtained near Hamburg as a new species under the name of *Acantholophus Hansenii*. In 1897 Mr Cambridge also described and figured the species in the *Proceedings of the Dorset Natural History Club* (vol. xviii. p. 114), from fresh examples sent him by Evans from a wall near Edinburgh in November 1896.

Our local records for this form are as under:—

Merchiston, Edinburgh, on wall, Aug. 1893, two; Gosford, East Lothian, on young conifer, Sept. 1893, two ad. ♀s; Comiston, etc., near Edinburgh, on walls, Oct. and Nov. 1896, several adults; Swanston, on pieces of wood, Nov. 1898, two.

Oligolophus ephippiatus (C. L. Koch).

Among a number of Phalangids collected on the banks of the Avon, near Torphichen, in the month of July, there are two specimens of this species. The only other Scottish record of it is for Argyll (Carpenter, *Ann. Scot. Nat. Hist.*, 1893, p. 222). We suspect there are also some *O. cinerascens* (C. L. K.) in this lot, but, being immature, they cannot be determined with certainty.

ADDITIONAL LOCALITIES FOR SPECIES ALREADY ON THE LIST.

Liobunum rotundum (Latr.)—Near Torphichen (Linlithgow), July; Aberlady, September 1896, adults common; Heriot (Midlothian), July 1897, common.

Phalangium saxatile (C. L. K.).—Kirknewton, two ad. ♂s, September 1895; near Edinburgh, October 1896, one; common under stones at high-water mark, Gosford Bay (East Lothian), 29th October 1897—specimens shown to Mr Cambridge.

Platybunus corniger (Herm.).—Wharry Glen, Bridge of Allan, several, and Carribber, Linlithgowshire, one, February 1898; etc.

Platybunus triangularis (Herbst.).—North Berwick Law, January 1896, a few.

Megabunus insignis, Meade.—On rocks, Tantallon Castle (East Lothian), January 1896, common; Binny Craig (Linlithgow), March 1898, a few.

Oligolophus agrestis (Meade).—The following winter records of this common species may be of interest:—Canty Bay, one, 29th December, Dirleton, one, 31st December 1895; foot of North Berwick Law, eight adults under stones, 2nd January, Swanston, three adults, 18th January, and Pentlands above Dreghorn, two adults under stones, 5th February 1896; Philipstoun, October, common.

Oligolophus tridens (C. L. K.).—Luffness Links, a few, August 1896 (identification confirmed by Mr Cambridge); Uphall, September, one; old quarry near Longniddry, common, September 1897; near Linlithgow, August.

Oligolophus palpinalis (Herbst.).—Swanston Wood, Pentlands, one, 28th October 1896 (confirmed by Mr Cambridge).

Nemastoma chrysomelas (Herm.)—North Berwick, December 1895, three; Longniddry, September 1897, one, adult; Kingsknowe, November 1898, one (R. Godfrey).

III. CHERNETIDEA.

ADDITIONAL SPECIES.

Chthonius orthodactylus (Leach).

In our notes on this order in 1895 (*Proc. Roy. Phys. Soc.*, Vol. XIII. pp. 122 and 123) we were able to record only one species for this district, namely, the common *Obisium muscorum* of Leach. We can now record two other species. The first is *Chthonius orthodactylus* (Leach), which we have obtained in two localities, namely, shore west of Aberlady, half a dozen specimens under stones just above high-water mark, 30th July 1896; garden in Morningside Park, Edin-

burgh, one under a board, 29th September 1897, and another in May 1899. It occurs, though rarely, in the south of England, and is also recorded from France. We know of no previous record for Scotland.

Chernes nodosus (Schrank).

An example of this species, taken in the herbarium at the Royal Botanic Garden, Edinburgh, on 27th August 1895, has been kindly handed to us by Mr J. F. Jeffrey. The Rev. O. P. Cambridge, who confirms our identification, has recorded the species from a number of English localities, the farthest north being Carlisle. It is usually found attached by the pincers of the palpi to the leg of a fly.

As bearing on the life-history of the False-Scorpions, Mr R. Godfrey tells us that, on the West Lothian shore, in the beginning of April 1899 he found three females of *O. muscorum*, each with a tiny white egg-cocoon attached to the under side of the abdomen, in cocoons (externally "like small balls of dirt") attached to a stone at high-water mark. We observed the same species in similar cocoons on the Binny Craig in March 1898.

XVII. *On the Genesis of Some Scottish Minerals.* By J. G. Goodchild, F.G.S., F.Z.S.

(Read 18th January, 15th February, 15th March, and 19th April 1899.)

The classification of minerals most commonly in use is that which is based upon both their chemical composition and their crystallographic form. There can be no doubt that such a classification is the most natural one that can be employed, and that it is the one which is best adapted to the requirements of scientific men in general. Other, and more artificial, systems, which better suit the requirements of practical men who do not concern themselves much with chemical principles, also find more or less favour. One of the best of these was employed by the late Professor Nicol in his "Mineralogy." Another, not less convenient, is used

in Rutley's admirable little book on Mineralogy.[1] The fine and extremely useful collection of minerals in the Jermyn Street Museum is arranged upon a plan somewhat similar to that of Nicol; as is also one of the sections of the Ferguson Collection at Raith, in Fifeshire. The needs of the geologist sometimes lead him to regard minerals more or less with reference to their origin; which he will probably continue to do, even though our knowledge upon the genesis of many species is as yet in a by no means satisfactory state; and although it may be very long before there is complete agreement amongst geognosers upon some of the questions connected with the genesis of some few of the species.

Now that the arrangement of the Collection of Scottish Minerals in the Edinburgh Museum of Science and Art is nearing completion, the time has come when it may be convenient to review the minerals with special reference to their origin. The Collection contains numerous specimens which yield important information concerning several minerals whose genesis is perhaps even yet imperfectly understood. A review of this kind, even if it serves no other purpose, may at least conduce to further inquiry, and to a critical examination of present and future evidence.

Scottish minerals may be classified with reference to their origin under two primary categories. The first of these includes all those minerals whose genesis is in any way connected with the combined action of cold surface-waters and gravitation, or which have been formed by agencies operating from above downwards. These may be conveniently designated Minerals of Epigene Origin. Practically, all the remainder are due to causes operating from within the earth's crust outwards. In most cases their genesis is connected with a high temperature, and with a manifestation of elevatory forces which counteract the effects of gravitation. These will be distinguished as Minerals of Hypogene Origin.

Presented in a tabular form, these, and their major subdivisions, may be shown as follows:—

I. Epigene Minerals.—Those due to changes arising from the joint action of cold surface-waters and gravitation, or

[1] Murby's "Science Series."

one or more of whose constituents are transferred from above downwards.

A 1. Those whose first stages consist in their being dissolved at the surface, and then redeposited elsewhere outside the lithosphere.

(*a*) Those deposited on the land.

(*b*) " " in fresh water.

(*c*) " " in closed bodies of water.

(*d*) " " at the bottom of the sea.

A 2. Those whose materials arise through solution at the surface, and subsequent redeposition within the lithosphere.

A 3. Those due to subterranean percolation of waters from the surface.

(*a*) Those which are there altered *in situ*.

(*b*) Those whose materials have been dissolved within the lithosphere, and subsequently redeposited at lower levels.

II. Hypogene Minerals.—Mostly of hydro-thermal origin, and usually connected with some manifestation of elevatory movement.

B 1. Original Minerals of Eruptive Rocks.

(*a*) Silicates.

(*b*) Metals and their Compounds.

(*c*) Other Minerals.

B 2. Original Contents of Mineral Veins.

B 3. Minerals arising from Solfataric Action.

B 4. Those deposited at the surface by Thermal Springs.

B 5. Those arising through Thermo-Metamorphism.

B 6. Minerals arising through Dynamic Metamorphism.

B 7. Combinations of the effects of B 5 with those of B 6.

It will probably be found on examination that there are few, if any, minerals occurring in Scotland whose origin cannot be referred to one or other of the above categories. In a few cases, as might have been expected, the same mineral species has arisen in more than one way. Hæmatite is a good example of this: usually it is due to the replacement of calcareous matter by the action of ferriferous solutions percolating downward, chiefly under desert conditions (A 2);

but it is due in other cases to solfataric action (B 3); and in others again, to pseudomorphous change (A 3). So with Muscovite (to take an example of a different kind). This, in Scotland, sometimes occurs as an original constituent of acid eruptive rocks, and is therefore placed under B 1. More often in Scotland it is a paramorph of Orthoclase felspar, and therefore comes also under B 6. Such cases as these are useful in bringing the geological side of mineralogy into due prominence; and they serve equally well to remind the geologist of his dependence in such matters upon the work of the chemist.

I. Epigenic Minerals.

A 1 (*a* and *b*). Under the first and second categories there are Scottish minerals whose genesis calls for special remark. Vivianite has been found in bogs in Shetland and elsewhere. It appears to be generally due to a combination of the phosphoric acid, derived from bones, with the iron usually present in the lower part of peat bogs. There exists some doubt whether crystallised specimens have yet really been found in Scotland. Limonite and its allies are due to the solvent action of surface-waters containing the humus acids and carbonic acid upon various other iron-compounds, whereby solutions of ferrous carbonate are formed. From these, partly through the action of organic matter, the ferric hydrate is formed. Some manganese compounds arise in a similar manner.

A 1 (*c*). Deposits formed in closed bodies of water — in many cases under desert conditions. The principal Scottish minerals formed under these conditions are Rock Salt, Gypsum, Dolomite, Hæmatite, one or two of the ores of manganese, and some concretionary forms of carbonate of lime. In the case of Rock Salt, the primary sources of the mineral may be fourfold. The salt may be simply washed out of some rocks in which it happens to occur; it may arise through the direct combination of sodium salts and others which yield hydrochloric acid; or it may be due to the evaporation of shallow pools of sea-water in areas tempo-

rarily shut off from the open sea. One contributory cause, which has been generally overlooked, is connected with the important fact that the aqueous vapour present in the atmosphere undergoes condensation most readily upon solid particles; and that, of all the solid particles present in the air, those of chloride of sodium are in this respect amongst the most potent. The water of the sea is lashed by the wind into foam and spray as it is driven against the rocks; much of the spray is transported inland by the same agent; its saline constituents are widely diffused, in the form of extremely minute particles of salt-dust, throughout all the lower strata of the atmosphere; and, finally, it is largely upon these saline nuclei that condensation eventually takes place. That chloride of sodium is ever present in meteoric waters has been abundantly proved by analysis—as much as thirty-two pounds per annum per acre having been recorded by Angus Smith from rain-water alone. Part, at least, of this is usually returned to the sea by rivers. But in the case of such river-waters as are largely or entirely dissipated by evaporation, the saline constituents are left. The shallow mouths of the rivers draining into the Caspian afford large quantities of salt which has thus originated; while at Kara Boghaz, on the eastern side of that inland lake, where the evaporation is exceptionally high, large quantities of salt are deposited.[1] The same occurs in nearly all the lakes of the Aralo-Caspian area, and, indeed, in all cases in which river-water is largely dissipated by evaporation. This is the reason why Chloride of Sodium occurs in such abundance in Lower Egypt, and in the Schats of Northern Africa in general, as well as in all other regions where similar geographical conditions obtain. In a region undergoing subsidence, layer upon layer of sediments thus impregnated with salt is laid down. Downward percolation of water redissolves it, transfers it to lower levels, and subsequently aids in concentrating it into one bed.

Rock Salt has hitherto been recorded from only two localities in Scotland. One of these is from Lower Carboni-

[1] One estimate places this quantity as high as 350,000 tons per diem.

ferous sandstones near Juniper Green, where large pseudomorphs of Rock Salt were pointed out to the writer by Miss Robina Orrock, of Edinburgh. These pseudomorphs probably represent crystals deposited from concentrated estuarine waters in a lagoon. Another occurrence is in the marls of the New Red,[1] near Kildonan, at the southern end of Arran. Here, also, the mineral is represented by pseudomorphs. There can be little doubt in this case that the Chloride of Sodium was formed under arid climatal conditions, and, possibly, in the warp of an old lacustrine delta.

Gypsum, the second mineral in this category, has likewise been formed under diverse circumstances, some of which may be conveniently noticed here. In a few cases it is due simply to the action of solutions derived from vitriolescent sulphides (usually Pyrites) upon solutions of carbonate of lime. Formed in this way, it is by no means of uncommon occurrence in Carboniferous shales. Good stellate groups so formed occur, for example, on the shore at Dalmeny, just east of the Forth Bridge. It also occurs in the same manner in the Yoredale shales on the Fife shore, about a mile N.E. of Kinghorn. A second mode of occurrence is in that of veins of Satin Spar, in which form it occurs in the Ballagan Shales (Lower Limestone Shales, d^1) of Tweedside. The veins probably represent what was formerly diffused sulphate of lime, formed under the subarid conditions which prevailed during the time when the Ballagan Beds were being deposited. These latter occurrences are probably due to occasional concentrations of estuarine waters in shallow lagoons, the sulphate of lime having been derived either direct from sea-water, or else from the solutions transported seawards by the rivers. More usually beds of Gypsum (which, however, have not yet been found in Scotland) represent what were originally thin films deposited upon surfaces of mud in inland lakes, and which films have been dissolved, carried to lower levels, and there redeposited in a concentrated form. Such

[1] This is employed here as a convenient general name for *any* of the Red Rocks which are intermediate in age between the Carboniferous and the Rhætic Rocks. A term having that meaning is very much needed.

deposits sometimes *replace* Dolomite; but more often *displace* clays and shales.

Dolomite, the third mineral in this list, has also been formed by more than one method. Most of the Scottish Dolomites are distinctly traceable to the alteration, *in sitû*, of ordinary limestones—the change having been effected chiefly, if not entirely, by the infiltration into the joints and other divisional planes of the limestone, of solutions of carbonate of magnesia derived directly or indirectly from the New Red Rocks. The vein-dolomites (Pearlspar), so well seen at Wanlockhead and Leadhills, may possibly be referable to downward percolation from the same source—for there is reason for believing that the New Red Rocks[1] (and therefore the Jurassic Rocks) formerly covered a large part of Scotland. Nearly all the druses found in the Scottish limestones of Carboniferous age are due to the contraction in volume of limestone when it enters into combination with carbonate of magnesia. The shrinkage may amount to as much as one-twelfth of the whole (see Heddle, *Trans. Roy. Soc. Edin.*, xxvii.). Beds of Dolomite, which can be shown to have been originally deposited as such, are rare or absent entirely from Scotland. Various compounds of the carbonates of iron, lime, and magnesia occur in Scotland, but it will probably come to be generally recognised that most of these are traceable to deposits from infiltrations from the New Red.

Some curious nodular and concretionary masses of carbonate of lime occur on at least two different geological horizons in Scotland. Both of these fall to be noticed here. The older of these forms the Cornstone Series, which marks the transition from the Upper Old Red Sandstone to the Ballagan Beds or Lower Limestone Shale. It is well seen in the sedimentary rocks of Salisbury Crags. It usually occurs in the form of irregular nodules; but may graduate into mere flakes on the one hand, or into irregular and impersistent interstitial deposits within the sandstones. These

[1] This is employed here as a convenient general name for *any* of the Red Rocks which are intermediate in age between the Carboniferous and the Rhætic Rocks. A term having that meaning is very much needed.

appear to the writer to be due to the reducing action of decomposing organic matter upon solutions of sulphate of lime, partially concentrated in areas temporarily shut off from the sea. In all cases they seem to be simply precipitates, some of which have remained where they were first thrown down; others have formed thin crusts, which have subsequently been broken up and redeposited. Most of them are contemporaneous with the formation of the stratum in which they now occur; while others appear to be due to secondary concretionary action. The whole series is of considerable interest, as marking a transition period between the arid climatal conditions of the Devonian Period and the humid climate of Carboniferous times.

The second horizon where these curious nodular limestones occur, is that of the Rhætic Beds, which bear exactly the same relation to the New Red below and the Jurassic Rocks above that the Cornstone Beds do to the Upper Old Red and the Carboniferous. Fine sections of these beds are exposed on the west coast of Mull, at Gribun, as well as in the adjacent island of Inch Kenneth. Beds of exactly the same nature occur in Elgin, at Bishopsmill, and other places near Lossiemouth. In all of these the Rhætic Cornstone Beds are excellently shown.

Lastly, the most important of these minerals is represented by Hæmatite. In connection with this I[1] have followed Mr Hudleston[2] in referring most of our British deposits of Hæmatite to an origin connected with closed bodies of saline water—especially during the New Red Period. There seems to be good reason for regarding Hæmatite, as it occurs in Britain, as practically all of New Red age; and this is true whether the deposit occurs in beds or in veins; or even where it simply stains the rocks into which it has been transported. A considerable mass of evidence points to the former existence of the New Red (and, therefore, of the Rhætic and Jurrasic Rocks) over a large part of Scotland and other parts of Britain, over all of which it has left its characteristic vestiges in the form of dolomi-

[1] *Trans. Edin. Geol. Soc.*, vii. p. 213. [2] *Proc. Geol. Assoc.*, xi. p. 104.

tised and ferrified limestones of older date, deposits of Hæmatite (which are almost invariably pseudomorphous after calcareous deposits) and sandstones stained red, which colour gives place to lilac, dull-puce, and purple tints, where the rocks so affected happen to have contained carbonaceous matter. Hæmatite is practically indestructible; hence the geological value of the evidence afforded by these red stained and ferrified rocks is considerable. Wherever these vestiges of the New Red occur, there also must have been both the Rhætic Rocks and also those of a Jurassic age, for in no part of Western Europe did the New Red occur without these strata succeeding it. I have repeatedly emphasised the significance of these facts, chiefly in relation to the comparatively recent origin of the mountains and valleys of North Britain.[1]

Some deposits of Manganese, and possibly a few of Gœthite and Limonite, may have originated in the same manner as Hæmatite.

No hard line can be drawn in every case between the origin of some of these lacustrine deposits and those formed at the bottom of the sea. The two chief Scottish examples of these are Pyrites, whose constituents colour the "blue clays" of Murray and Irvine,[2] and the nodular deposits of Manganese described by the same authors.[3]

A 2. The chief Scottish minerals referable to this category have already been noted incidentally.

A 3. Those due to the subterranean percolation of waters from the surface.

(*a*) Those altered *in sitû.*

To this section must be referred a large number of those minerals that have undergone pseudomorphic change by the action of water. In addition to the pseudomorphs, commonly understood as such, there are the well-known examples of Serpentine and Kaolin, as well as a few others

[1] *Trans. Cumb. and West. Assoc.*, viii. p. 888; *Trans. Edin. Geol. Soc.*, vii.; *Trans. Glasgow Geol. Soc.*, xi.; and other places.

[2] Murray and Irvine, *Trans. Roy. Soc. Edin.*, xxxvii. [3] *Ibid.*

of less common occurrence, such as Pinite, etc. Under this category must also be placed Agalmatolite, which appears to stand in the same relation to Oligoclase as Kaolin does to Orthoclase. Saussurite may, likewise, originate in the same manner from Anorthite.

(*b*) Those whose constituents have first undergone solution within the lithosphere, and have subsequently been redeposited at lower levels.

This also is an important section, including as it does the whole of the Zeolites and the minerals allied to them in origin; and also Agates and various other forms of silica. The rocks in connection with which the minerals under this category occur are chiefly those of eruptive origin. The number of mineral species whose origin may be classed under this heading is considerable; but it will suffice for the purpose in view in the present article to notice one or two representative groups of each set.

The prime factors concerned in the changes to which these minerals are due appear to be water charged with Carbonic Acid, which is principally derived from the atmosphere, and with the allied Humus acids, which originate from the decomposition of organic matter, chiefly through the action of bacteria. In the case of an eruptive rock—of which we may take an andesite as a typical example in the present case—the weak solutions of acids percolating from the surface begin by attacking certain of the constituents of the rock—the sodium compounds amongst others. These are sooner or later converted into solutions of sodium carbonate, which, although very much diluted, are yet able to set up important chemical reactions as they slowly make their way downward through the body of the rock. One after another of the constituent minerals of the rock begins to give way, and the process is continued until, after a considerable length of time, all the outer crust of the rock is completely decomposed—a small part of the dissolved constituents being transferred in solution by the percolating waters to positions within the sounder rock below; while rivers transport the remainder in the direction of the sea.

The various stages in the formation of Scottish agates will very well serve as a general illustration of what ensues. These are found in vapour cavities, which vary much in both form and size, and may be faulted or otherwise deformed before they begin to be filled. They are usually closed in, on all sides, by solid rock. These cavities are filled entirely by solutions carried in by osmosis. The first solutions so transported from the solid rock to the cavity below are usually those of the ferromagnesian constituents, which are, in the case under consideration, usually Augite. These solutions gradually coat the walls of the cavity, probably as a succession of thin films, which are deposited from very weak solutions. They form what may be termed the "priming," upon which subsequent coats of other substances are afterwards laid. The "priming" varies in composition with the nature of the rock from which it has been derived; but its nature, in general terms, may be said to be more or less allied to Serpentine. Its colour is usually green, nearly that of moss, or, better still, of an ivy leaf. Various names have been given to this green "priming," but Dr Heddle (who devoted much attention to these matters, and to whom the present writer is indebted for much of his knowledge of this subject) finally concluded, after long consideration, that the mineral in question was Celadonite.[1] Commonly the deposition of Celadonite at any given level below the surface terminated at an early stage—and, indeed, in some cases the deposit is so thin that it is practically absent altogether. But, in other cases, its formation may have continued long past the stage where it formed simply a "priming" to the interior of the cavity. In some few cases the deposition of this or an allied saponaceous mineral evidently went on until the cavity was completely filled. It was occasionally deposited quite alone; while in many other instances it formed a mechanical mixture, combined in various proportions with chalcedonic silica. True Moss Agates were thus formed, and where the mixture had been more intimate, Prase, Heliotrope, or Bloodstone was the result.

[1] Dr Heddle preferred to spell this "Celedonite," in which form it appears in the "Mineralogy of Scotland."

A little later than the time when Celadonite has begun to coat the interior of the cavity, weak solutions of silica-jelly, in a form which is destined to become Chalcedony, begin to be carried in by osmosis in the same way as the Celadonite was before. There is abundant evidence to show that this stage of agate-formation was often accompanied by a rupture of the previously formed layers of Celadonite, by the ingress of the solutions containing the Chalcedony. The saponaceous nature of the Celadonite seems to have been very favourable to its easy removal. As a consequence, shreds and ragged filaments of the ivy-green mineral were gradually torn from the walls of the cavity, and eventually became coated with film after film of the silica-jelly, until, in the end, the filaments of Celadonite became completely enveloped within the chalcedonic material. Eventually the solvent of the Chalcedony began to escape, the material coagulated, and finally hardened, and then the filaments of the ivy- or moss-green Celadonite became enveloped in the Clear Chalcedony and thus simulated moss.

All *true* Moss Agates were thus formed. Mochas are different in origin, and will be described further on, in their proper place.

More usually the "priming" of Celadonite is not coated directly by the Clear Chalcedony Layer just mentioned, for the felspars present in the rock have usually begun to give way at a stage closely following that of the initial stages of destruction of the ferromagnesian silicates. These products of decomposition of the felspars were carried in through the rock, through the walls of the cavity, and thence through the layer of Celadonite, by osmosis, which carried in the solutions, and deposited them, and which, in turn, also favoured the expulsion of the aqueous solvent after it had deposited its load. By this partial destruction of the felspars, and the redeposition of the dissolved material in a solid form, a layer of Zeolites was deposited. The precise nature of the Zeolite must, of course, have varied with the nature of both the solvent and the material acted upon. In Scottish Agates, Natrolite and Heulandite seem to be the commonest of these; though there can be no doubt that other species were formed in exactly the same manner.

In some cases little zeolitic matter, or even none, was deposited, and the layer was usually very thin; but the deposit resembled that of the Celadonite in taking place uniformly over every part of the wall of the cavity. Occasionally the deposition of the zeolitic matter went on until the greater part or even the whole of the cavity was filled. This has often happened in one cavity close to another in which the deposit from first to last has been that of the Celadonite. In other cases it may be close to another cavity which contains a perfectly-formed agate. It is by no means clear why adjacent cavities, penetrated, it is to be supposed, by solutions which are alike, should, in one case, contain chalcedony, in another—distant, perhaps, only a fraction of an inch—should contain a serpentinous mineral, while a third may contain an agate, a fourth Calcite, and a fifth remain unfilled. Yet such is the fact.

Leaving this to be explained by the results of future investigations, we may revert to the third layer in the order of deposition, the Clear Chalcedony Layer, already noticed incidentally. Whether the Celadonite layer, or the Zeolite layer, be absent or not, this Clear Chalcedony Layer appears to be present in most, if not in all, agates. It uniformly coats every part of the cavity, and follows all the ins and outs of its surface, to whatever cause these inequalities may be due. This curious fact of a material deposited from solution adhering to both the roof and the sides of a cavity, as it were in defiance of gravitation, is regarded as due to the powerful surface tension which exists, on the one hand, between those solutions of silica which are destined to become Chalcedony, and each of the three substances upon which it may be deposited, on the other. It is well known that there is a difference of degree in the surface-tension between any single fluid and a solid of any other kind; or, conversely, that between any solid and any one of all other fluids; the surface tension being often greatest between any given solid and a fluid tending to deposit crystalline matter. Chalcedony is usually regarded as a mixture of colloid silica—virtually Opal—with crystalloid or crystalline silica, which may be Quartz, or Tridymite, or, it may be, a third form of crystallised

silica, theoretically considered as Quartzine, but whose precise mineral nature does not yet appear to have been satisfactorily determined.

To sum up, so far:—Three layers may be deposited within an agate, which follow each other in definite order—Celadonite, Zeolite, and Clear Chalcedony—and each of which as a rule, uniformly coats the surface formed by its predecessor. We shall do well to follow Dr Heddle in terming these three layers collectively as the Skin of the Agate.

Sometimes it happens that the Clear Chalcedony Layer has continued to be deposited layer upon layer to a thickness so great that Gravitation began to turn the balance against the opposing force of Surface Tension. Then, very much the same thing began to occur as would happen if several coats of paint were to be laid one upon another upon a ceiling, each coat before the former one had begun to dry. The Celadonite began to sag a little here and there; and once it yielded at any point, any subsequent deposit, while yet in the gelatinous condition, tended to elongate the pendant portion under the influence of gravitation. In a few cases, notably in Faroe, and at Norman's Law, in Fife, coat upon coat of silica-jelly had been deposited in solution, and stalactitic masses, pendant from the roof of the cavity, or of many projecting points elsewhere, have been formed. It was in this way that Stalactites in Agates have originated. Now, Surface Tension is increased proportionately with increase of surface. It therefore follows that, as the Stalactites lengthened, they offered an increased surface as compared with that of any similar basal area in other parts of the cavity. More silica, therefore, was deposited near where there were Stalactites than anywhere else within the cavity; and, for the same reason, more was deposited in the space between two contiguous stalactites than was deposited elsewhere. Hence, notwithstanding the advantage that Gravitation had at first in its conflict with Surface Tension, the latter force eventually gained the ascendancy, and accomplished most in the end. We shall presently see that a consideration of the effects arising from this contest between Surface Energy and Gravitation affords us the clue to under-

standing nearly all the structural features of agates; while a clear conception of the operation of Osmosis gives us an equally trustworthy clue to the history of the enigmas presented by the remainder.

With the completion of the Clear Chalcedony Layer there often arose yet another change. Probably the earlier-formed layers had by this time consolidated, more or less. The change referred to is the formation of minute tufts, probably representing a second crop of zeolites, which arose, sporadically, here and there upon the "skin." Their precise nature does not appear to have been yet made out, not even by Dr Heddle, who had thousands of sections of agates cut for microscopic examination, and had microscopes specially made for this work. Minute as they certainly were, in every case their effect upon the succeeding structures must have been very important. We may realise the principle upon which these effects depend, by remembering that Surface Energy acts proportionately to the surface-area concerned. If, within a given space, the surface-area can be increased relatively to the volume of space within which it stands, the effects of Surface Tension will be increased in proportion. A loosely-rolled ball of worsted will present a total surface-area many times in excess of that of a wooden ball of the same diameter; and the area presented by the leaves and stems of a bush may be more than a hundredfold that of the surface-area of a box in which the bush could be packed without compression. If, therefore, even a small roughness should arise upon an area elsewhere smooth, any solutions tending to deposit upon the whole area would deposit in larger quantities where the rough part of the surface presented itself than where it was smooth. In accordance with this principle, it will be readily understood that any chalcedonic solutions carried into a cavity where even minute tufts had arisen would deposit in larger quantities over them than elsewhere. And as Surface Energy constantly tends to a minimum, the form of each succeeding deposit tended to become that of a hemisphere, because that form of surface offers the smallest area of any solid of the same dimensions. Therefore, each succeeding coat of Chalcedony tended to

build up successive shells of a hemispherical form; and as the composition of each layer often differed, within certain limits, both in structure and composition, from those with which it was associated, these shells, when subsequently cut and polished, usually exhibit a series of concentric rings of different colours, which may be likened to eyes. In this manner are Eyed Agates formed. There are few agates which do not show at least some traces of these.

Usually these "eyes" are formed at the stage just referred to, but the process may occasionally be repeated at various stages later in the developmental history of the agate, with much the same result.

Where "eyes" occur in an agate, it will be seen that after the hemispherical stage has been reached, the succeeding layers, if of Chalcedony, tend to conform more and more to the general shape of the interior of the cavity, so that the successive zones over each eye gradually change their form as they approach the centre, passing first into layers that are nearly flat, and then becoming slightly concave towards the centre as they grow beyond the influence of the earlier irregularities.

Where the growth of two or more eyes brought them into contiguity, the form of the layers deposited between them tended first to assume that of sharp re-entering angles, and then, with further growth towards the centre, caused them to merge into simpler curves. Cross-sections of an agate so formed are known as Fortification Agates, from the fancied resemblance of these salient and retiring angles to the plan of certain forts.

In all the foregoing notes on agates it has been assumed that the solutions of silica carried in by osmosis have been deposited very slowly, and in very thin layers at a time. Many agates which happen to have been formed of layers varying in composition and in colour show this very well. It is not uncommon to meet with examples in which several hundred layers can be counted in the thickness of a single inch, and even these layers themselves may consist of numerous others of greater tenuity still.

It has further been assumed for convenience of descrip-

tion that the solutions have carried in chalcedonic materials alone. In actual fact this is rarely the case. The chalcedonic matter has often been deposited as a mixture, sometimes with zeolitic matter, in which case the material becomes more or less opaque on consolidation, and usually somewhat chalky in aspect. This, in the case of chalcedonic matter, may be called chalcedonic Cachalong. But the solutions are by no means always chalcedonic. Taking Scottish agates as a whole, one may say that nearly a fourth of the silica carried in consists of colloid or quite amorphous silica, combined with a variable quantity of water, which may range to twelve per cent. or even more. Such a compound is known as Opal. It has already been mentioned as forming the basis of Chalcedony—which is Opal minus most, or all, of its water, and plus a variable percentage of crystalline or crystalloid silica. There seems reason, therefore, for regarding Chalcedony rather as a *mixture* than as a compound having a definite composition. In a few cases, and especially towards the end of the period of agate formation, the opaline constituent diminishes to nothing. In that case Quartz or Amethyst results.

This variability in the percentage of opaline silica carried in is of considerable importance in the history of an agate. Solutions depositing pure Opal conform wholly to the laws of Gravitation, and are in nowise affected by Surface Tension. That is to say, a solution depositing Opal-Silica does not coat the sides or the roof of an agate cavity; but the layers subside entirely to the bottom, and arrange themselves in absolutely horizontal positions, even at their edges, where they abut against the sides of the cavity. The deposition of Chalcedonic Silica, it will be remembered, is controlled more by Surface Tension, and may therefore be deposited in even larger quantities on the roof or the side of the cavity than on its floor. Mixtures, in variable proportion, of opaline silica with chalcedonic silica commonly occur. Where the opaline silica predominates, Gravitation comes most into play. Where the chalcedonic silica forms the chief ingredient in the mixture, Surface Energy prevails. Now, it is quite clear from the study of large numbers of agates, such as those

under the present writer's charge in the Edinburgh Museum, that the nature of the solutions carried in by osmosis varied within wide limits, and that, too, often at close intervals. When solutions of opal-silica were carried in, the particular layer thus formed arranged itself as horizontally as the fluid in a spirit-level. When solutions tending to become chalcedonic silica followed, these deposited layers which conformed at the base to the opaline layer, but, at the sides, climbed the dome above, and coated that part as much as the parts below or even more so. Solutions of intermediate composition comported themselves according as the one constituent or the other predominated. It may be remarked here that layers of horizontally-deposited silica are usually termed Onyx—a name, it must be remembered, which may include Opal, Chalcedony, and their modifications, and has reference only to the parallelism of the layers, and not to their composition.

Many agates containing Opal bands have previously developed "eyes." Where these are covered by Opal, sections show that the eyes were simply submerged by the rising deposit, which abuts against the eyes abruptly. But where Chalcedony has encountered these prominences, it has obeyed the usual law, and has enwrapped the eyes conformably to their shape, as already noticed. The difference in comportment is very striking, and cannot fail to attract attention in the case of such a collection as that above referred to.

Like the chalcedonic silica, the opaline form often includes an admixture with zeolitic matter. This forms the true Cachalong.

Not uncommonly the central portion of an agate may remain unfilled. When this is the case, the last-deposited layers usually crystallise out as either Quartz or Amethyst —probably because no opaline matter was present in the last stage of growth.

There is reason for believing that the consolidation of the siliceous contents of an agate occupied a long time, and that both the lower opaline layers and the Clear Chalcedony consolidated at an earlier stage than the agate layers, properly

so called. The evidence presented by a large number of specimens shows that when the agate cavity had become quite filled with silica-jelly, and before this passed from the coagulated to the solid state, osmotic pressure still continued in operation. Modern investigations have shown that the osmotic pressure from without increases with the density of the solution within the cavity, and that the pressure exerted by the solution within the cavity obeys the same law of expansion under a rise of temperature as gases have long been known to do (Boyle's Law). The increase of internal pressure after the agate cavity had become filled, consequent upon the operation of one or the other of these causes (probably that of continued osmosis), — it is possible that the rise of temperature of the nascent agate, consequent upon partial crystallisation of its silica, may have contributed to the same result,— eventually caused one or more ruptures of the walls of the agate. This usually commenced at some point where the "skin" was somewhat thinner than elsewhere, or where the walls of the agate cavity presented a weaker spot than was to be found in other parts. A minute orifice usually resulted; and, through this minute orifice, the unconsolidated part of the Agate was slowly forced out, like oil colour out of a tube. The layers nearest the Clear Chalcedony were the first to be expelled, and then gradually followed the other layers successively nearer the centre. This curious feature Dr Heddle (to whom we are indebted for an explanation of its true nature) gave the name of the Tube of Escape. There is always more or less dilatation of the tube next the Clear Chalcedony Layer, so that the form of that part of the tube very much resembles that of a Florence flask. The tube itself may always be recognised by the fact that the layers next to it are more or less attenuated, and are also bent outwards in the direction of the external orifice. It is to this curious feature that some of the most striking irregularities of structure seen in agate sections are due.

In many cases it will be seen that the vacant space left by the expelled silica-jelly has subsequently been refilled by a second generation of agate material. There may even be a

third. Dr Heddle has pointed out that the Tube of Escape is always the last part to be filled.

True agates, *i.e.*, those formed in closed cavities, are normally slate-grey, lavender, or dove coloured, and are very rarely coloured red or yellow through any ferruginous material contemporaneously introduced. Vein-Agates, on the other hand, which are formed in fissures and other cavities communicating more easily with surface-waters, often contain iron as a colouring constituent. Where this is introduced in only small quantities, and in the form of ferric oxide, it occurs scattered throughout the chalcedony in the form of minute spheroids. This gives rise to Carnelian, which is blood-red and translucent Chalcedony. Where the iron, or the other impurities, are introduced in larger quantities, so that the Chalcedony is rendered opaque, Jasper results. No true Opal appears yet to have been found in Vein-Agates in Scotland.

Much of the red coloration often seen in Scottish agates is due to subsequent infiltration, as is clearly shown by many specimens in the Scottish Agate Collection. The colouring matter is usually ferric oxide, and it has probably been derived from the Upper Old Red. It affects the Chalcedony, and not the Cachalong.

For some reason which is not yet apparent, agates in Britain, and probably elsewhere, are chiefly confined to andesitic lavas, and they occur mostly in those of the (Caledonian) Old Red. It may be mentioned here that perfectly-formed agates, evidently derived from the lower Old Red lavas, commonly occur in the conglomerates of the Upper Old Red Sandstone. The agates must, therefore, have been formed at some time between the close of the earlier and the commencement of the later period.

Some of the changes that affect agates after their formation has been completed are of general interest, as bearing upon other mineralogical questions. Amongst these is the fact that the red staining just referred to is often bleached out, wholly or in part, as a consequence of exposure at the surface. As this change is regarded as not due to the action of the humus acids, it may perhaps be referred to the prolonged

action of weak solutions of nitric acid derived from the soils. Another change is molecular, and arises from the tendency of opaline silica to part with its combined water, and thus to pass into the crypto-crystalline, or even into the crystalline, condition. There is usually some loss of volume with this change, and in a few instances the layer affected develops a kind of jointed structure, through the formation of divisional planes perpendicular to the bounding surfaces of the layer in question.

After agates have been affected by weathering at no great depth below the surface, percolating waters sometimes carry in solutions of various substances into any crack which may have been formed within the agates. Amongst these solutions, those of manganese are by no means uncommon in certain localities. From these there is often deposited the hydrous oxide, which, in passing into the solid condition, usually does so in dendritic and moss-like forms. These are usually black or brown in colour. Agates containing these dendrites are called Mochas. The true Moss Agate is a contemporaneous structure, is normally green in colour, and is due to Celadonite enveloped in Clear Chalcedony, as already mentioned above.

Under the influence of contact metamorphism, agates pass into crystalline Quartz, and their Celadonite into Epidote. This is well seen in some agates from near Tillicoultry, as well as at Glencoe. The Withamite of the Old Red lavas of Glencoe is clearly due to this cause.

The various stages in the history of an agate are full of interest, not only for the student of Mineralogy, but also to the geologist, as many of the processes which have operated on a small scale in the case of an agate exemplify what takes place on a scale of much greater magnitude in connection with rock-masses of all dimensions.

The formation of siliceous concretions, such as the nodules of flint and chert in limestones, has been brought about by processes which in all essential particulars agree with those concerned in the formation of agates. In the case of the flint and chert, however, the materials have often *replaced* an

equivalent volume of calcareous matter, instead of being deposited within a space formerly vacant. This fact of replacement is, again, of interest in its bearings upon the origin of eruptive rocks, and will be referred to in this connection further on. It is beautifully shown in the geyserites of the Bathgate Hills, as well as in those of other localities in Scotland.

II. Minerals of Hypogene Origin.

These have been formed chiefly by hydrothermal agencies, generally at a considerable depth below the surface; and their subsequent exposure is due in all cases to the combined effects of upheaval and denudation.

B 1. The Original Minerals of Eruptive Rocks.

(*a*) Silica and the Silicates.
(*b*) Some Metallic Compounds.
(*c*) Accessory minerals, such as Sphene, Zircon, Orthite, Apatite, etc.

Section (*a*). These naturally group themselves into (1) Quartz and Tridymite; (2) the Felspars and the Felspathoids; (3) the Amphiboles and the Pyroxenes; (4) Olivine; (5) the Micas.

So far as their origin is concerned, Sections (*a*), (*b*), and (*c*) may be considered together; as, in whatever manner they may have arisen, that mode of origin has been common to them all.

At the present day it is usually considered that all eruptive rocks have been formed by actual fusion; and by many writers they are regarded as arising from subterranean cisterns, where their materials are supposed to have remained in a fluid state from the earliest periods in the Earth's history. Other observers are disposed to regard them as re-melted forms of older eruptive rocks, which had formerly been in a solid state.

A few years ago it was a common belief among field geologists, even amongst those of wide experience, that in many cases eruptive rocks represented simply an extreme

form of metamorphism of old sediments. Those who held that view attributed the change from the one type to the other to the action of hydro-metamorphism—that is to say, these geologists recognised *water* as the most important factor concerned. Even those who no longer adhere to this latter view still regard water as one of the factors concerned in the genesis of eruptive rocks, though they are, perhaps, disposed to regard its presence as incidental rather than as essential.

Every student of geology has long been aware of the fact that enormous quantities of aqueous vapour are given off during volcanic eruptions. And, again, most chemists recognise that eruptive rocks have been formed, at least, in the presence of either water itself, or else of its constituents, in some form.

Nevertheless, there are at present very few geologists, and probably still fewer petrographers, who would be prepared to go further in the direction indicated by these facts, and who would be willing to consider whether, after all, eruptive rocks may not have arisen mainly through the action of water. It is quite true that no one is yet in a position to express positively an opinion either for or against any of the currently received views, and it is with some diffidence, therefore, that I venture to put forward an hypothesis relating to this very much disputed subject of the origin of the eruptive rocks, which is based upon the assumption that they are deposits from aqueous solutions.

The facts which, in addition to those already mentioned, have led me to formulate these conclusions are not now generally called in question by field geologists. Foremost amongst these stand a large number of cases connected with the mode of occurrence of intrusive masses, which demonstrate that these intrusive rocks do not *displace* the rocks they invade, but actually *replace* them, as if by some process of pseudomorphism. That is to say, where a given thickness of intrusive rock occurs, an equivalent volume of the rocks invaded has in some way disappeared. For example: if we take the case of two coal-seams which are normally separated by 100 feet of other rocks of sedimentary origin,

and these rocks happen to be invaded along the bedding places by an intrusive sheet of dolerite 50 feet in thickness, the two coal-seams are not found in such a case to be 150 feet apart, as might have been expected to be the case, but are seen to remain 100 feet apart, just as if the newer rock had not been introduced at all. Even in hand specimens the same fact may be studied. I have lately presented one such, from Aberdour, in Fife, to the Edinburgh Museum; and many others showing the same feature can be observed in the field, on all scales of magnitude. Moreover, it is a fact well known to coal-miners that "sills cut out the coal-seams." Geologists also have long been familiar with the fact that granite and diorite bosses do not thrust aside the rocks they invade, but act as if they had simply eaten their way up through them. These are facts, explain them how one may.

On the other hand, there is the equally well-known fact that eruptive rocks do not vary in composition with lithological changes in the rocks with which they are in contact; but in many cases they retain a marvellous uniformity of both composition and structure, over hundreds of square miles, and are the same in composition where they invade limestone, as where they come into shales or into masses of sandstone, and have no higher percentage of lime silicates, or of compounds of alumina, or of silica, in each of these three respective cases than in any others. (It may be remarked that these notes are being penned in North Westmorland, close to the outcrop of the Whin Sill, which exemplifies all these points admirably.)

Several years ago Mr Clough read a paper before the Geological Society of London, in which he advocated the view that in such cases as that of the Whin Sill the eruptive rock had *assimilated* the rock of sedimentary origin, and he endeavoured to show that, taking the bulk-analysis of these sedimentary rocks over the whole of the area where the intrusive rock is seen, that it would be possible to explain the facts by assuming that the composition of the whole mass of these would, if equalised, suffice to furnish the materials which analysis showed to be present in the Whin Sill itself. The view did not then meet with a very favourable reception

—perhaps because it was advanced before its time. The chief objection put forward against its acceptance was the very obvious one above referred to, that the Whin Sill did not vary in composition with the rocks in which it occurred.

The view here presented may be regarded as a modification of Mr Clough's. It may be stated as follows:—

If we examine the evidence afforded by the analyses of eruptive rocks on the one hand, and of sedimentary rocks on the other, it becomes evident that the two differ chiefly in the percentage of alkalies present. In the case of the eruptive rocks the quantity is relatively large, and is small in the case of the others. On this account no mere rearrangement of the constituents of any normal sediment would suffice to convert it into any kind of eruptive rock; but if it is possible by any means to restore the alkalies which epigene causes have removed, then, and only then, does the reconversion become possible. Hence it becomes a question of much interest and importance to inquire by what means any such restoration of alkali can be rendered possible.

There are two possible sources; but, concerning them both, it must be confessed that at present we can form little more than a conjecture. One of these may be connected with the uprise of heated waters from below, which, it is at least conceivable, might bring up sufficient quantities to effect in time the result in question. The other, upon which I am disposed to lay very much more stress, is, in one sense, epigene in origin. It is supposed to take place beneath the floor of the ocean—mainly within that marginal region which forms the Transitional Zone between the line of mean sea-level and the seaward margin of the land, and which is now generally recognised as the zone of chief terrestrial activity. Alkaline carbonates are ceaselessly being transferred in solution from the rocks of the land to the sea by the agency of rivers; and that transference must always have been in progress. Hence, unless there is some natural agent, organic or inorganic, which is constantly at work using up these materials as fast as they arrive, in the same manner as organisms use up the lime-salts, it is obvious that the quantity must go on increasing, which we have no

reason to believe is really the case. No organic agency yet known to us is engaged upon the work; and we are therefore led to speculate whether the cycle of change may not be completed by the gradual transfusion by osmosis, of the superabundant alkaline matter, through the floor of the ocean, most especially within the zone of chief terrestrial mobility above referred to as the Transitional Zone. Osmosis may thus be supposed to carry these aqueous solutions downwards through the outer portions of the submarine parts of the lithosphere, to those horizons beneath the surface where the temperature sufficient for dissolving rock-material is to be found. This depth need not be very great, nor need the temperature be very high, for the experiments made by Daubree, Delesse, and others, show that alkaline solutions are quite able to dissolve silica and most of the silicates—if sufficient time be allowed—at a temperature some hundreds of degrees below that required for dry fusion. (It is at least conceivable that the temperature exhibited by lavas when they reach the surface may be far above that at which their liquefaction commenced within the lithosphere: but upon this point, again, we have little or no exact information.) It appears to me that nothing more is required than such conditions as these, and I can see no difficulty in accounting for the conversion of sediments into gneisses, for their replacement by any kind of eruptive rock, or for their conversion into those aqueous solutions which give rise to lavas, if the factors just referred to operate in the manner suggested.

This view of the purely aqueous origin of the magmas of eruptive rocks is alike compatible with the fact that, under one set of conditions, fluidity may be generated at a lower level, whence the magma is bodily transferred to a higher by the explosive force exerted by its heated H_2O, and, under another set of conditions, what eventually becomes a crystalline eruptive rock may be generated and consolidated without any such transference. In the case of the formation of a sill or a dyke, for example, all that appears to be necessary is the forcible injection of heated alkaline waters, in the first instance, along some divisional plane of the rock that is being

invaded. Such a solution, continuing to act at a moderately high temperature, gradually dissolves the materials of the rock, while the fluidity of the magma favours the equalisation of its composition by convection and diffusion throughout the whole of the part affected. After a time, the conditions begin to change, the temperature falls, the aqueous solvent mostly escapes, the various constituents of the magma gradually crystallise out, each in the order determined by the pressure and the temperature proper for the crystallisation, and in course of time the whole passes into the condition of a solid mass of rock. On this view of the origin of eruptive rocks their plutonic and trappean forms may be regarded as PSEUDOMORPHS.

It should be noted that the change of state from solid to liquid, in the case of most of the rock-forming minerals, takes place at definite temperatures and abruptly; so that the line between the dissolved and the undissolved rock must, on the whole, be usually well defined. At the same time, it is quite conceivable that some of the constituents might pass from the solid into the fluid condition sooner than others. In this way one can easily account for the introduction of certain minerals into the rock invaded, and also for that solution and redeposition of silica which has converted sandstones into quartzites, and shales into Lydian stone, in the contact zones of eruptive rocks. It has long been known that heated waters charged with alkalies are capable of producing upon coal-seams all the effects seen in the case of their contact with intrusive masses, and that they are able to do this at a comparatively low temperature. The "burnt coal-seams" of the miners are, therefore, not necessarily due to dry heat.

An impartial consideration of these theoretical views regarding the origin of the eruptive rocks will serve to show that they explain many other facts observed in the field besides these above referred to, and that they will also satisfactorily account for many of the phenomena of both contact and dynamo metamorphism, to be referred to in more detail presently.

B 2. The Original Contents of Mineral Veins.

Mineral veins, such as those of Wanlockhead and Leadhills, containing a large number of mineral species, are probably of considerable geological antiquity; while others, containing a small number of species, may well be comparatively recent in oiigin. If these veins are regarded in a very broad and general way, they appear to be referable to two great classes:—(1) those whose contents have arisen from below and have ever since remained nearly in their original condition; and (2) those whose constituents, in whole or in part, have formerly been at a higher level than they are at present. It is with those belonging to the first category that we have here to do.

It has long appeared to me that the only satisfactory explanation of the origin of the normal type of mineral veins is that it represents a series of deposits from thermal waters which have risen from the heated interior of the Earth's crust in the direction of the surface, and have deposited the substances they originally held in solution when they started, one after another, on the walls of the cavity, in accordance with the temperature which determines the depositing point for each species. The great majority of mineral veins either occupy fault-fissures or else are closely connected with these zones of communication between the interior and the exterior of the Earth. It is assumed that thermal springs are connected directly or indirectly with volcanic action—usually they appear to mark the waning of a volcano. It is highly probable that the number of mineral substances held in solution by the thermal waters is proportionate to the elevation of temperature. As the waters rise in the direction of the surface, the depositing temperature of one mineral substance after another is successively reached, until, by the time the spring reaches the surface, very few of the numerous substances of which it was formerly the vehicle still remain in solution.

It should be noted that the zone where any given substance is deposited from solution varies with the thermal conductivity of the rock it is traversing, and, also, with the lowering of temperature consequent upon the deflux of

cooler waters which are making their way downwards from the surface. This latter cause, in its turn, largely depends upon the form of the surface, as well, also, upon the nature of the rocks—whether these are highly permeable or the reverse. The position of the isogeotherms may be affected also by other causes, even, to some extent, by climate. But the surface configuration at the time when the hot springs are in operation is probably the most important modifying cause now, as it must always have been in the past. I am disposed to attribute to this cause the remarkable disposition of the metalliferous parts of the mineral veins of the north of England, whose upper limits rise to higher levels beneath what are now hills, and sink to a corresponding extent below what are now valleys. This fact is very strongly suggestive of the explanation that those veins have been filled with their latest contents in comparatively-recent geological times, and at a date when the present river courses had been already established.

There is another point connected with the vertical distribution of ores in certain metalliferous districts which calls for some explanation. It is found, in many cases, that if a series of transverse sections are run across one of these districts where mineral veins are worked, and if the position of the zones where any given ore, such as Galena, occurs in greatest quantity, are carefully plotted on the sections, these points, if connected with each other all round, tend to outline a meniscoid whose convex surface is upward. It is found that if the highest position at which ore occurs in one of these districts be noted, the position of the same ore in the veins around gradually declines in all directions from that point. Of course the vertical extent through which ore may be found in any one vein varies greatly with the nature of the mineral and with the character of the rocks. Galena rarely extends through more than a thousand feet, and usually seems confined to a few hundred. Chalcopyrite has a higher vertical range—perhaps because it was formed at a greater depth.

The explanation of the meniscoid form of the deposit is

probably that the highest point in the surface marks a position which at one time lay above the focus of the group of thermal springs to which the deposits of ore are supposed to be due, and around which the temperature of the thermal waters was lower at the same plane above the sea-level. Mineral substances deposited in the fault-fissures around, would of necessity be laid down in accordance with the position of the depositing temperature proper to each species; and if all the zones where deposition took place are connected by imaginary lines, these would be found to outline, as it were, a series of shells, concentric to the focus of the hottest spring, and with those minerals lowest which require the highest temperature to keep them in solution, and the others at various higher horizons, whose positions are determined by the factors already noticed.

It may be remarked that these observations and speculations, although of a very general character, are based upon a long and careful examination, both at the surface and in the mines, of a very large number of metalliferous deposits.

Hot springs vary in temperature from time to time. Hence it follows that, in the case of a rise of temperature, previously-formed minerals are wholly or in part dissolved, and their constituents are redeposited at higher levels; or, with a fall of temperature, minerals whose depositing temperature is low, are laid down upon others which, at an earlier stage, were deposited from hotter water.

All mineral veins appear to have been formed during periods of terrestrial disturbance, apparently during those accompanying upheaval. With any elevation of the land the rock-masses are subjected to lateral tension, and hence the cheek, or walls, of pre-existent faults are stretched wider apart with each successive uplift—except in those cases where compensation ensues through wedges of rock slipping downwards and thereby filling up the vacant space. Such lateral severances, if they happen to occur at a time when the fissures are being coated with mineral veins, stretch the previously-formed veins asunder, and permit of new deposits being laid down between the dissevered walls. Hence arises

the "comby" structure of mineral veins. Hence, also, raises the association of various minerals which have been deposited under different conditions of temperature.

Lastly, reverting to the statement that mineral veins represent the waning efforts of volcanic action, it must be borne in mind that fault-fissures and volcanic eruptions have been formed at various and widely-separated periods, in Scotland as elsewhere. Hence it might be expected to be the case that the contents of the Scottish mineral veins are of very diverse ages. Some of them may possibly date from as far back as the Devonian Period—though this is not very likely to be the case. Others may have been formed at the close of the Carboniferous Period of volcanic activity. A third set may have originated with the advent of the Keuper Marl. A fourth may date from Miocene times (which appears to be that to which most of the lead-veins of Yorkshire belong). Furthermore, a set of mineral veins formed say, during New Red times, and subsequently altered by surface agencies, are likely to have afforded channels of egress for the hot springs of Miocene times. Complicated interactions may thus frequently have resulted. Such veins as those of Leadhills and Wanlockhead, as well as the corresponding veins of Galloway and those of the Caldbeck Fells in Cumberland, may well have had a history of the kind just referred to. In that case there is little need for wonder at the varied and complex nature of their mineral contents.

B 3. Minerals arising from Solfataric Action.

There is no clear evidence of any Scottish minerals having arisen directly through this agency, unless they are to be found in certain minerals of secondary origin, which occur in the hearts of the great volcanic centres of Tertiary age, such as those of Rum, Mull, Skye, etc.

B 4. Nor is it quite certain that any Scottish minerals, except the Chalcedony in some bands of old Geyserite, can properly be referred to this category.

B 5. With regard to those minerals that arise from Thermo-metamorphism, or, rather, through metamorphic changes set up by Hydrothermal action, the case is very different. A large number of the most important of the Scottish minerals are due directly, or indirectly, to this cause.

These may be divided into two sections: in the one the constituents of the minerals resulting from the change were already in existence in some form or other within the rock in which they now occur; in the other case, one or more of the constituents have been introduced from some source exterior to the present nidus of the minerals in question.

The first section may conveniently be subdivided, in accordance with the nature of the predominant constituent of the rock affected, as follows:—

If that predominant constituent is calcareous—the lime being associated with impurities consisting of various other substances—these latter, after the rock has been long exposed to the solvent action of water at high temperatures, and, also, presumedly, under considerable pressure, may eventually separate out in more-or-less crystalline, and often idiomorphic forms, when these conditions of temperature and pressure change. A great variety of minerals may thus arise. In Scotland, the commonest minerals developed by this molecular rearrangement are Idocrase, Cinnamonstone (and, occasionally, Grossular, and in a few instances one or two other forms of Garnet), Sahlite and its varieties, Tremolite, Wollastonite (but not Pectolite), Zoisite, Apatite, Sphene, Andesine (but not Anorthite), normal Biotite (but not Phlogopite in Scotland), Muscovite, Pyrrhotite, Spinel, Talc, and Forsterite. Serpentine, which is found in metamorphic limestones, is probably a secondary product of some ferro-magnesian mineral. The occurrence of these minerals is strongly suggestive of the conclusion that the original limestone has slowly undergone solution and subsequent recrystallisation *in situ*. Other facts seem to confirm this.

In the cases where alumina predominates in the rock the same heated waters may bring about a partial solution of some of the constituents, and a subsequent molecular re-

arrangement, which results in the formation of Kyanite, Staurolite, Andalusite, Fibrolite, Cordierite, Biotite, some Garnets and Pyrites. Secondary enlargements of felspars and Quartz are due to the same cause.

Graphite, which probably represents, in this case, carbonaceous matter originally diffused through sediments, is developed in the form of fine scales in some of the rocks in the contact zones around the Galloway granites. There are good specimens of these in the Scottish Mineral Collection, from near Creetown. Very similar graphite schists, probably due to much the same cause, occur on certain horizons in the Highland Metamorphic Series.

Anthracite occurs in Scotland under two forms, both of which are here regarded as connected with the uprise of heated waters. The commonest, well represented by the oft-described coal-seam at New Cumnock in Ayrshire, has originated *in sitû*, probably through the action of heated alkaline waters connected with the formation of a contiguous intrusive mass. The other case is well represented by the Anthracite found in the Lower Carboniferous tuffs of the Calton Hill, near Edinburgh, and in the (possibly) Tertiary agglomerates so well displayed on the shore of the Forth between Elie and St Monance. These occurrences of Anthracite may well be due, in the first instance, to the formation of metallic carbides, which, by subsequent chemical changes, have been converted into purer carbon. I have elsewhere ventured to suggest that even the Diamond may have been formed in this way.

Where arenaceous matter forms the predominant constituent, the number of minerals developed appears to be inversely proportionate to the purity of the rock. Calcareous impurities may give rise to some of the minerals above mentioned under "limestone," and argillaceous matter may be rearranged so as to form some of the minerals mentioned in the last paragraph. Pure quartz-sand remains nearly as originally deposited; the grains, at the most, undergoing mere secondary enlargement through the deposition of silica derived from beds on a higher horizon. The conversion of

sandstone into quartzite, and of shales and clays into Lydian stone, near their contact with dykes and sills, is here attributed to deposits of silica from the heated alkaline waters which form the "mother liquor" of the eruptive rocks.

Where the rock affected happens to be one of eruptive origin, the new minerals developed always bear a definite chemical relation to the constituents of the rock affected. Amongst the minerals most commonly developed in rocks of sub-basic composition by thermo-metamorphism are Garnets [1] and Epidote. In the case of an andesite in which the vesicles once contained Saponite or Celadonite, these pass into Epidote. Not uncommonly some part of the decomposition products of the ferro-magnesian minerals may again return to the form of their parent minerals, and Delessite and its allies just referred to may redevelop into one of the Amphiboles. In like manner some part of the zeolites may go back again to felspar; and Chalcedony, Opal, and other colloidal and semi-colloidal forms of silica may go back to Quartz. Fine examples of this latter change are shown by the agates in Ordovician lavas of the English Lake District, where they are pierced by granite masses; and still better in the Old Red Andesites of the Ochils, where they come near to intrusive masses like the Tillicoultry diorite. Where the Arenig Radiolarian Cherts come near to the granites of Galloway, the colloidal silica is also converted into granular Quartz.

The second division (*b*), which comprises those minerals resulting from hydrothermal action, in those cases where some part of the constituents have been introduced from without, form a connecting link with B 1. As an example, not already referred to, may be mentioned Tourmaline. Practically most of the remainder occurring in Scotland have been referred to already; but this may be the right place to remark that some of the minerals already referred to as generated in metamorphic limestone, may be partly due to

[1] The great majority of garnets appear to be due to the thermo-metamorphism of rocks which are primarily of eruptive origin.

the introduction of some constituent from an outside source, such as alkalies, from sea-water.

Another, and very important, effect of this kind of hydro-metamorphic action manifests itself in connection with volcanic rocks. As a volcano increases in size (of course, mainly by additions to its exterior), the lines of equal internal temperature (the volcanic isogeotherms) keep pace with its growth, and probably remain at nearly the same depth below the surface of the cone throughout all stages in the history of the volcano. It follows from this that the temperature of the H_2O permeating the central part of a volcano increases with the growth of the cone. It ensues as a natural result that a gradual re-softening of the earlier deposited beds of lava, tuff, and intrusive masses, may commence soon after they have been deposited. In those cases in which this stage is reached before the volcanic rocks have lost any of their alkalies, a molecular reconstruction of the constituents must necessarily arise. In this process, there can be no doubt that many fragments of crystals which were ejected during explosive eruption have been "mended," and others have increased in size by additions to their exterior. Furthermore, as tuffs usually consist of little else than fragments of what would have passed into rocks of holocrystalline structure had the fluid mass remained long enough undisturbed by explosive forces, a comparatively slight change suffices to convert these fragments into rock undistinguishable from lava, or even, in extreme cases, from one or other of the plutonic representatives of such effusive rocks. The importance of the fact in question cannot be doubted. A recent visit (June 1899) to the Ordovician rocks of the English Lake District has convinced me that a large part of the volcanic rocks which are regarded by many petrographers as lavas, are really, as Mr Aveline and the late Mr J. C. Ward considered them, simply pyroclastic rocks thus altered contemporaneously.

Mention has more than once been made above to the fact that some of the andesitic tuffs which have been thermo-metamorphosed next the diorite of Tillicoultry, in the

Ochils, show this metamorphic change very well. The feature is equally well exhibited by the tuffs of the same age (Devonian) which occur under similar conditions in Lanarkshire. Those of the English Lake District which have been thus affected belong to two very different types, which may be classed according to whether their alteration has been effected contemporaneously (as it has been in most cases), or whether the alteration has taken place long subsequently, as in the case where those Ordovician volcanic rocks have been invaded by granite masses during Devonian times. The distinction is of much geological importance, but it appears to have been previously overlooked. In the former case the rocks may gradually change *in sitû* into holocrystalline rocks, in the latter, typified by the tuffs in the contact zones around the Shap Granite, this reversion to a crystalline character is much less likely to take place.

B 6. Minerals which arise through Dynamic Metamorphism.

The exact nature of some of the processes by which the minerals referable to this category have been formed must always remain more or less doubtful, because they have certainly come into existence under conditions which it is impossible to imitate experimentally. Still, evidence obtained from a study of their mode of occurrence in the field, throws at least some light upon their history; while a careful comparison of a large series of hand specimens, such as are exhibited in the Edinburgh Museum, enables us to confirm and extend the conclusions arrived at after a study of the rock-masses on the larger scale in the field.

Like some of the minerals previously referred to, these under notice appear naturally to group themselves under two leading categories. Under the first range those minerals the whole of whose constituents, there is reason to believe, were already in existence within the minerals which formed the parent source. The second embraces those minerals which appear to have arisen partly through the introduction of one or more constituents from a source outside.

To the former category must be referred such changes as the conversion of Amphibole into Biotite by dynamic causes, of which very fine examples occur in many parts of Scotland; and also the better known case of the conversion by dynamic causes of potash felspars into Muscovite. Many Biotite schists and Muscovite schists have arisen in this way, mainly, of course, in the more ancient rocks. The genesis of both Muscovite and Biotite offers a most interesting and instructive example of the fact that almost any mineral may originate in two or more ways. There can be no doubt that Biotite (using this name in its widest sense) does occur as an original constituent of some eruptive rocks; it is also one of the most common products of contact-metamorphism; and there can be no doubt that Biotite is due in other cases to the paramorphism of Hornblende, which mineral itself may once have been one of the Pyroxenes. Nay, further, Biotite may arise in connection with the minerals coming under the next category. The case of Muscovite presents an almost parallel instance. It is undoubtedly an original constituent of some highly silicated eruptive rocks, though it is not of common occurrence in that connection in Scotland. It is certainly developed in a few cases by thermo-metamorphism. As a product of the dynamic metamorphism of arkoses and other clastic rocks of felspathose composition, such as the Torridonian arkoses, as well as of eruptive rocks containing potash felspars, it is one of the commonest and most widely diffused of Scottish minerals. Furthermore, like Biotite, it certainly does arise in connection with the minerals whose origin falls next to be described. We may take these as typical examples of minerals whose origin is due to dynamic metamorphism.

When we come to consider the origin of the various minerals which are due in some way to the effects of dynamic metamorphism operating concurrently with the introduction of constituents from an outside source, we find ourselves face to face with some of the most difficult problems in the whole field of geognosy. It has long seemed to me that the whole question of the origin of these various minerals re-

solves itself into a consideration of the processes by which the enigmatical rocks known as Pegmatites have originated. I have elsewhere speculated upon one or more possible means by which these pegmatites may have been formed. It is true that these speculations were based chiefly upon an indoor study of specimens which are in the Collection of the Geological Survey, and in the still finer series in the Scottish Mineral Collection; but I have also made the most of several opportunities of studying these pegmatites in the field. The sequence of causes to which these appear to me to be due is as follows:—First, a slow crushing, perhaps repeated more than once. Granulitic structure follows as a consequence of the *later* movements. This structure reduces the rock material to a condition in which its constituents present a relatively large surface area, which thereby greatly facilitates subsequent chemical change. The energy of motion arising from the earth movements may generate sufficient heat to anneal the granulitic compound, but even in the cases where the temperature is not sufficiently high to produce that result, it may tend, especially if alkaline waters (from the bed of the sea or other sources) be present, to bring about fusion. The pressure raises the fusing-point, and counteracts this tendency to pass into the fluid state. But local relief of pressure now and then ensues, whereupon the potentially fluid mass is placed under conditions which favour molecular rearrangement. The process of change is usually a slow one, equally towards the fluid condition and towards the solid condition which afterwards ensues. Hence coarsely crystalline structures are developed, and types of combinations of crystals (graphic, micrographic, and granitic structures), which can only arise under plutonic conditions and under pressures which, although always great, yet vary in amount in different cases.

I am inclined to lay special stress upon the probability of these processes having usually been of extreme slowness. If that was really the case, there does not seem any valid objection to the view that, with the introduction of alkaline waters under great pressure, any mass of old sediments

XVIII. *The* Collembola *and* Thysanura *of the Edinburgh District.* By GEORGE H. CARPENTER, B.Sc., F.E.S., and WILLIAM EVANS, F.R.S.E. [Plates V., VI., VII., VIII.]

(Read 15th February and 19th April 1899.)

[*Preliminary Note by W. Evans.*—As many of the Fellows of the Royal Physical Society are probably aware, I have long had an ardent desire to see the fauna of the picturesque country in the midst of which our romantic city stands thoroughly investigated, and have already laid before the Society several papers as contributions towards that end. That which I now have the honour to submit deals with a group of small and much-neglected, but nevertheless highly interesting, and, under the lens, often truly beautiful creatures, concerning which I have learned much in the course of the past three years—thanks once more to my friend Mr Carpenter of the Dublin Museum, through whose hands (as in the case of the Spiders and Phalangids) all my specimens have passed. But for the constant stimulus provided by his hearty co-operation in the identification of the specimens, the material on which the subjoined list is based would in all probability never have been collected by me. From other quarters, also, help and encouragement in a variety of ways have not been wanting, and are gratefully remembered: especially pleasant is the memory which my correspondence with Prof. Reuter of Helsingfors, Dr Schäffer of Hamburg, and Dr Schött of Upsala, leaves behind.

In the case of such minute animals as a large proportion of the Spring-tails are, anything entitled to be regarded as an exhaustive catalogue for the district could, of course, only be drawn up after many years of special and continuous research. I am well aware, therefore, that the present paper, founded as it is mainly on material collected during little more than three years, and then, as a rule, only when I was in search of other things, must partake more or less of the nature of a preliminary list, certain to be very considerably extended as time goes on. Meantime it will at any rate serve as a

an earthquake is due, and to the continued action of which is also due the expulsion of volcanic matter to the surface. The discharge of thermal springs, and the liberation of their dissolved contents, is yet another result of the same cause.

At those depths where the pressure is greater, but the quantity of alkaline solutions carried down is less, a slow conversion of the sediments into gneiss takes place.

The formation of eruptive rocks and gneiss, and, in short, all volcanic and seismic phenomena, are, on this view, traceable, directly or indirectly, to the osmotic transference of alkaline solutions to the sediments below the Transitional Belt of the lithosphere; that is to say, the chief agent concerned works from above downwards.[1] Is anyone prepared to demonstrate that such a transference cannot take place?

In conclusion, I must frankly admit that some of the foregoing speculations relate to matters concerning which our present knowledge is very imperfect, and is likely to remain so for many years to come. Nevertheless, hypothesis have their uses in geology perhaps more than in any other science. If there are several ways of accounting for a given set of facts, it is at least well to give them all careful consideration, and even those that are least in accordance with the views current for the time being may guide future thinkers to the road that leads to the actual truth.

[1] Since this paper was written, Professor Cargill G. Knott has read a paper on Earthquakes before the Royal Society of Edinburgh (10th July 1899), in which he demonstrates that the interior of the earth is in the condition of an elastic solid. The view of the origin of eruptive rocks here advanced was formally read before the Royal Physical Society on the 19th of April 1899, and was given in outline before the Geological Society of Glasgow on 30th May 1898 (see the *Glasgow Herald* for 31st May 1898). It will be seen that it is in perfect harmony with the view advanced by Professor Knott.

[The present author communicated an essentially similar view to the British Association, at the Nottingham Meeting, September 1893. Ref. Sec. C, p. 761.]

XVIII. *The* Collembola *and* Thysanura *of the Edinburgh District.* By George H. Carpenter, B.Sc., F.E.S., and William Evans, F.R.S.E. [Plates V., VI., VII., VIII.]

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record of the majority of the species now to be found here; and perhaps it may be the means, directly or indirectly, of bringing about that fuller list which is bound some day to make its appearance.

In giving the local data so fully in this and other similar papers, I have been influenced largely by a desire that they should be available for any topographical "census," or county lists of the groups, that may in the course of time be attempted. Some slight account of the Edinburgh district in its zoological aspects will be found in previous papers.]

The Collembola (Spring-tails) and Thysanura (Bristle-tails) are best known to British naturalists through Lubbock's "Monograph" (7), published by the Ray Society in 1873. During recent years our knowledge of the species of these insects has been increased mainly by the labours of North-European investigators — Tullberg and Schött in Sweden, Reuter in Finland, and Schäffer in Hamburg. Their works, which deal with the species mentioned in our list, are enumerated at the end of the present paper, and most of the forms now recorded for the first time as British will be found fully described in one or other of them. The beautiful monograph of Schött (15) has been especially valuable for the identification of our captures, and has supplied us with much information as to the geographical distribution of the various species.

In cases where revision of the synonymy has led to a change in the name under which a species stands in Sir John Lubbock's "Monograph," the latter when known has been inserted after the one now used; but a number of the forms mentioned in that work cannot be recognised with any degree of certainty, in consequence of the descriptions containing little or no reference to those minute structural characters now chiefly relied upon. It would be well if these doubtful points in synonymy could be cleared up, and we are glad to hear from Sir John, with whom we have had some correspondence on the subject, that he thinks of taking up the matter himself in the near future.

Our list includes four species of Thysanura and fifty-nine of Collembola.[1] Reuter's list (12) of species obtained by him in Scotland enumerates only one Thysanuran and twenty-one Collembolans. Four of these latter, however, namely—*Entomobrya lanuginosa* (Nic.), *Isotoma cæca*, Reut., *I. crassicauda*, Tullb., and *Anurida crassicornis*, Reut., have not been detected by us near Edinburgh. Regarding *I. cæca* and *A. crassicornis*, we would remark that they were new to science, and have not since been met with anywhere. The descriptions are unaccompanied by figures, and unfortunately, as we are informed by Professor Reuter, the types have been lost. So little is said by Lubbock as to the range of species in the British Isles, that it is impossible to state with certainty how many of the forms entered in our list are new to Scotland. His detailed localities refer almost exclusively to England—he only twice or thrice uses the term "Great Britain," and only once mentions a Scottish locality, namely, St Andrews. It would seem, therefore, that he had practically no information regarding the group from north of the Border, and that we may fairly claim as first Scottish records nearly all those concerning forms not mentioned by Reuter. But be this as it may, we have the satisfaction of introducing at least seventeen species[2] new to the fauna of Great Britain, namely—*Sminthurus novemlineatus*, Tullb., *S. bilineatus*, Bourl., *S. violaceus*, Reut., *S. igniceps*, Reut., *S. malmgrenii*, Tullb., *S. cæcus*, Tullb., *Pseudosinella cavernarum* (Mon.), *Entomobrya marginata* (Tullb.), *Isotoma maritima*, Tullb., *I. grisescens*, Schäff., *I. sensibilis*, Tullb., *I. cinerea* (Nic.), *I. fimetaria* (Linn.), *I. spitzbergenensis*, Lubb., *I. schötti*, D. T., *Xenylla humicola* (O. Fabr.), and *Achorutes longispinus*, Tullb. The majority of these are characteristically northern

[1] The number of Collembola in the list when submitted to the Society in February 1899 was forty-eight. Five additions, namely—*Sminthurus malmgrenii*, *S. cæcus*, *Pseudosinella cavernarum*, *Achorutes longispinus*, and *A. manubrialis* were subsequently reported at the April meeting; and these, together with six others since discovered, namely—*Sminthurus novemlineatus*, *S. bilineatus*, *S. quadrilineatus*, *S. igniceps*, *Lepidocyrtus curvicollis*, and *Triæna mirabilis*, are now incorporated in their proper places.

[2] Three of these—*Sminthurus cæcus*, *Pseudosinella cavernarum*, and *Isotoma schötti*, have, however, been recorded from Ireland by Carpenter.

forms, one of them (*S. violaceus*) being hitherto known only from Finland, another (*I. spitzbergenensis*) only from Spitzbergen, and a third (*A. longispinus*) till lately only from Novaya Zemlya.

Comparing our list of Collembola with the lists of 101, 89, and 80 forms—a number of which, however, are not in our opinion really distinct—recorded from Scandinavia (6, 15), Finland (11), and the country around Hamburg (13), respectively, it appears that only eight of the Edinburgh species are unrecorded from Scandinavia, as against ten absent from the Finnish list and fourteen from the Hamburg one. Most of our species are widely distributed over the Palæarctic region, and several of them extend their range far beyond its limits—indeed, the exceedingly wide distribution of some forms is peculiarly interesting. The range of *Sminthurus hortensis*, for example, extends from Scandinavia and Scotland to Japan on the one hand, and America (both North and South) on the other; *Isotoma palustris* ranges from Novaya Zemlya and Siberia to Bismarck Archipelago, throughout Europe to the Azores, California, and La Plata; while outside of Europe *Achorutes viaticus* is recorded from places as far apart as Greenland, Behring Island, and Tierra del Fuego. The absence of *Orchesella villosa* (one of our rarer species) from the Sandinavian and Finnish lists seems to show that it is a more decidedly southern form than most of the others. *Papirius ornatus* (a common form with us) has a very similar range, only it goes up to the western (Norwegian) side of Scandinavia. *Anurida maritima*, and the Thysanuran *Machilis maritima*, neither of which are in the Finnish list, are apparently confined to the shores of the Atlantic.

It is difficult to say exactly how many species have been recognised in the British Isles. Roundly the number may be stated at about seventy-five Spring-tails and four Bristle-tails (excluding one or two foreign importations); of these, all the latter, but only sixty-three of the former, have as yet been detected in Scotland. But seeing that the Collembola are a hardy race, and so largely represented in Northern Europe, we have every reason to anticipate that future investigations will add materially to the list of Scottish species.

It would not have been surprising had one or two species new to science been detected among the large number of specimens that have passed through our hands. There are, indeed, among them a few which differ in some respects from typical examples of the forms under which we have recorded them, but we feel satisfied there is nothing in any of these differences to warrant specific separation. In this group, colour and size are very variable, and even some of the structural characters now so much relied on—the relative length of the antennal segments, and the number of teeth on the foot-claws and on the mucrones—are undoubtedly subject in many cases to more variation than has generally been supposed. Careful comparison of a large series of specimens from different countries and localities would, we believe, show that a good many so-called species are not worthy of more than varietal or at most sub-specific rank.

A large proportion of the species of this group of insects subsist on decaying vegetable matter, fungi, and confervæ; but some undoubtedly feed on living plants of higher orders.

We are deeply indebted to Prof. Reuter, Dr Schäffer, and Dr Schött, the three eminent Continental authorities on the Collembola, for having favoured us with their opinions regarding a number of specimens submitted to them for comparison with Continental types, and for other valuable assistance.

SYSTEMATIC LIST OF SPECIES.

Order COLLEMBOLA.

Family **SMINTHURIDÆ.**

Genus **Sminthurus,** Latreille.

Sminthurus fuscus (Linn.).

This species, which is widely distributed in the Palæarctic Region, ranging at least from Austro-Hungary to Ireland and from Northern Europe to North Africa and the Azores, occurring also in South America (La Plata), seems to be by

no means common in the valley of the Forth. We have only met with it, as yet, in the two localities undermentioned.

Local data.—Rosslyn Woods (Midlothian), Oct. 1897; oak wood behind Aberfoyle (W. Perth), half a dozen among dead leaves, Sept. 1897.

Sminthurus viridis (Linn.).

Widespread and fairly common in the district among grass and other herbage throughout the summer and autumn months. The only named varieties we have noted are var. *cinereoviridis*, Tullb. (which seems commoner here than the typical form), var. *dorsovittatus*, Reut., and var. *multipunctatus*, Schäff.

This variable insect has been recorded from Novaya Zemlya, Russia, Hungary, Tunis, Ireland, and numerous intermediate countries, as well as from Japan and La Plata, so that its geographical distribution seems to be even more extensive than that of the preceding.

Local data.—Among mint in garden at Morningside (Edinburgh), July 1896, common, some fairly typical; Morton, near Edinburgh, July and Oct.; Pentland Hills, above Currie, var. *cinereoviridis*, off heather, Oct. 1897; Braid Hills, May 1898; Luffness (E. Lothian) and Elie (Fife), common among grass, etc., mostly said var., Aug. 1896; Uphall (Linlithgowshire), a few, one of var. *multipunctatus*, Sept. 1896; near Dunfermline (Fife), Oct. 1897; Edgelaw (Midlothian), Oct. 1898; Kirknewton (Midlothian) and Inverkeithing (Fife), var. *cinereoviridis*, common in May and July; Bavelaw Moss (Midlothian), several of type, and one of var. *dorsovittatus*, July; etc.

Sminthurus novemlineatus, Tullb., var. **insignis,** Reut.

[Plate VI. Figs. 1-4.]

The rich yellow unstriped variety (*insignis*) of this species is locally common in summer on heather, cotton-grass, sedges, etc., in boggy places both inland and on the coast. The typical nine-striped form we have not yet seen.

The long bristles on the inner side of the dentes, and the broad elliptical mucrones, serve to distinguish this species, which is recorded from Norway, Sweden, Finland, Russia, Germany, and Bohemia—the var. *insignis* from the first three countries only.

Local data.—Wet spots on Bavelaw Moss, at the base of the Pentland Hills (Midlothian), July 1899, common; damp places on Longniddry Links (East Lothian), August, common; Ochils (Kinross), Sept.

Sminthurus bilineatus, Bourl.

[Plate VI. Figs. 5-8.]

As yet we know of only two localities for this tiny form, the principal one being Bavelaw Moss, at foot of the Pentland Hills, where it occurs rather plentifully on heather during the summer months. Dr Schäffer has kindly examined some of our specimens, and confirmed our identification.

Structurally this species and the preceding one are very closely related, as was indicated by Tullberg (16) many years ago. Apart from size and coloration, the distinctive features are to be found in the spring. The feet and the antennæ (distinctly ringed in both forms) are very much alike. In Schäffer's key (13) to the genus, *S. bilineatus* is placed in the section with 4th antennal segment, "nicht deutlich geringelt," which is certainly misleading. And as regards Tullberg's divisions "Setosi" and "Pilosi," we much doubt if any satisfactory line can be drawn between them. At any rate, it seems to us that if *novemlineatus* be placed in "Setosi," so also should *bilineatus.*

Tullberg included Lubbock's *S. bourletii* in the synonymy of the present species, but we venture to think this was a mistake. As we shall show further on (p. 229), everything points rather to the identity of Lubbock's insect with *S. quadrilineatus,* Tullb. Abroad *S. bilineatus* is recorded from Scandinavia, Finland, Russia, France, Germany, and Sardinia.

Local data.—Bavelaw Moss, near Balerno (Midlothian), June and July, common on heather; Ochils, north of Milnathort, Sept., a few.

Sminthurus hortensis, Fitch.

Sminthurus pruinosus, Tullb. (16), and *S. lineatus,* Reuter (10*a*).

[Plate V. Fig. 1; Plate VI. Figs. 9-12.]

In the summer of 1896 this species occurred in considerable numbers in gardens at Morningside Park, Edinburgh, and

at Aberlady, in Haddingtonshire. We have also met with it on several occasions on the margins of fields, and even on a moor at the foot of the Pentland Hills. In one locality we find, besides the dark typical form, a colony of a bright yellow variety, which Dr J. W. Folsom of Cambridge, U.S.A., informs us is the var. *juvenilis* of Fitch; its colour, however, is clearly quite independent of age. In some examples of this variety purplish-grey markings and blotches are more or less apparent, giving them a somewhat intermediate aspect. We have almost invariably found the dark typical form on the bare ground. The identity of the North American *S. hortensis*, Fitch, with the European *S. pruinosus*, Tullb., has recently been established by Dr Folsom (5), who has kindly sent us specimens of the American insect (both type and yellow variety) in exchange for some of our Scottish specimens, that we might see for ourselves how perfectly they agree.

We know of no previous British record for this species except that of Reuter (12), who found it in Moray, Orkney, and Shetland. Abroad it is recorded from Sweden, Finland, Russia, Germany, and Bohemia, North and South America (Tierra del Fuego), and Japan.

Local data.—Morningside Park, Edinburgh, common, July 1896 (and again in 1899), on garden footpath; Aberlady (E. Lothian), a few in August; Bavelaw Moss (Midlothian), a few on bare peaty places, June 1899; grass fields at Ormiston, near Kirknewton, type and var. *juvenilis*, fairly common, but quite apart, July; Parkly Craig (Linlithgow), a few on edge of farm-road, August.

Sminthurus luteus, Lubb.

[Plate VI. Figs. 13-15.]

This dainty little Spring-tail—in which, it may be mentioned, the three pairs of feet are all closely alike—is abundant here on grass, clover, and other herbage in meadows, and on the banks of ditches, etc., during the summer half of the year. Elsewhere in Scotland it has been found by Reuter (12) in Moray and Orkney, and Evans has taken it in the north of Perthshire. Lubbock (7) speaks of it as "very common, among grass," presumably in the south of England. Abroad it ranges from Scandinavia and

Finland to Bohemia and Sardinia, and it is also recorded from Siberia, California, and La Plata. It appears to us very probable that this is the *S. lupulinæ* of Bourlet.

Local data.—Rosslyn (Midlothian), June, abundant on grass, clover, etc., on moist spots on the banks of the Esk below the chapel; near Midcalder, common on grass at the side of a ditch, July; Inverkeithing (Fife), on banks of a stream, July; Tynehead (Midlothian) and Longniddry (E. Lothian) on *Lotus major*, etc., Aug.; Parkly (Linlithgow), common on *Vicia cracca*, Aug.; etc.

Sminthurus quadrilineatus, Tullb.

? *Sminthurus Bourletii*, Lubbock's "Monograph."

[Plate VI. Figs. 16-19.]

The typical striped form of this species occurs sparingly upon pieces of dead branches lying on the ground in a grass field on the farm of Lawhead, parish of Midcalder. Along with it, but much more plentiful, is a dark sooty-coloured form, structurally identical, and evidently the variety *ochropus* of Reuter. Superficially this latter form bears a strong resemblance to *S. niger* on the one hand and *S. igniceps* on the other—the pale yellowish legs, yellowish colour of the first and second antennal segments, and usually of the forehead and crown as well, being suggestive of an intermediate form. The structure of the mucro, however, which has perfectly plain margins in all the specimens we have examined, at once distinguishes it from *niger*, and indicates a very close relationship to *igniceps*, from which, nevertheless, it differs appreciably in the form of the feet and mucro. The habitats too are different. Some examples, which we propose to designate var. *flavescens*, are entirely of a brownish-yellow colour.

The identity of Lubbock's *S. bourletii*, from Kent, with the present species seems to us highly probable. Judging by the figure of the antenna of Lubbock's insect, given in the *Transactions of the Linnæan Society*, vol. 26, they agree exactly as regards this organ; and the "very finely serrated" inner margin of the mucro, spoken of in the description of *bourletii*, is not inconsistent with their identity, for Dr

Schäffer tells us the mucro is sometimes faintly toothed in *quadrilineatus*.

The only other Scottish locality known to us for *S. quadrilineatus* is Blair Atholl in Perthshire, where the sooty variety was found by Evans in September last. On the Continent it is recorded from Sweden, Finland, and Germany.

Local data.—Lawhead farm, near Midcalder (Midlothian), eight specimens of the typical form, about thirty of var. *ochropus*, and a few of var. *flavescens*, June and July 1899.

Sminthurus violaceus, Reuter.

[Plate V. Fig. 2; Plate VII. Figs. 1-4.]

A few specimens of this minute species, which has hitherto been known only from Finland, whence it was described by Reuter (10*b*), and figured by Schött (15), were obtained in August 1896, in a garden at Aberlady by means of a white cloth spread on the ground in order to attract various kinds of small insects, and render them at same time more easily seen. It is a beautiful little Spring-tail (only about ·75 mm. in length), to be recognised by its rotund body, comparatively short antennæ with fourth segment not ringed, and divergent dentes which are inserted laterally on the manubrium, not touching each other at their bases. The mucrones in our specimens are denticulate to the tip. Schött's figure shows the teeth ceasing at about half the length of the mucro; but even if this difference between Scottish and Finnish specimens be confirmed, it cannot be reckoned as of specific value. Neither can the reduction to a small vestige, in our specimens, of the distinct tooth figured by Schött on the upper claw of the front foot.

[Since the above was written we have found this species in some numbers at Morningside, Edinburgh. Most of the specimens from this second locality have the upper part of the head, and a few the forepart of the body as well, deeply tinted with yellow.]

Local data.—In garden at Aberlady (E. Lothian), 30th Aug. 1896, several obtained, but unfortunately only two preserved; Morningside Park, Edinburgh, July 1899, fairly common on garden foot-path.

Sminthurus niger, Lubb.

Except in a greenhouse in an old garden in the south side of Edinburgh, we have failed to detect this species in the district. Owing to its small size ($\frac{2}{3}$ mm.) and dark colour it is, however, easily overlooked. Reuter found a single example in Orkney, and Lubbock's specimens were obtained in his garden in the south of England. Widespread on the Continent—Sweden, Finland, Germany, Austria, Italy, and Sardinia; also recorded from Siberia and the Argentine. We have compared our specimens with examples kindly sent to us by Dr Schäffer from Hamburg. Some palish markings are distinctly visible on both sets.

Local data.—Newbattle Terrace, Edinburgh, Aug. 1898 and June 1899, fairly common under flower-pots in an old greenhouse.

Sminthurus igniceps, Reut.

[Plate VI. Figs. 20-23.]

This form also is an inhabitant of greenhouses in the suburbs of Edinburgh. It may not be indigenous to the district, but this is a point on which we are scarcely prepared to offer an opinion.

S. igniceps was described by Reuter (10*b*) in 1878, from specimens got in orangeries in Helsingfors, Finland; and it has since been obtained in hothouses in Germany, Norway, and Sweden. It is closely allied to *S. niger*, but may be separated from that at a glance by its bright yellow head and antennæ, pale legs, and more uniform velvety-black colour of the body. Schött (13) describes the margin of the mucro as either quite plain or very faintly denticulate. In all our specimens denticulation, though slight compared with that in *S. niger*, is quite perceptible (see Fig. 23).

Local data.—Morningside Park and Newbattle Terrace, Edinburgh, May and June 1899, fairly common under and about flower-pots in greenhouses.

Sminthurus malmgrenii, Tullb., var. **elegantulus,** Reut.

[Plate V. Fig. 3; Plate VII. Figs. 5-8.]

This is another minute, but none the less beautiful northern Sminthurid which it gives us much pleasure to be able to

add to our (and the British) list. Although the localities in which we have as yet detected it are comparatively few, we have no doubt that further research will show it to be widely distributed in the district. It is an aquatic species, inhabiting the margins of pools and ponds, where it may be observed skipping on the surface of the still water, or resting on the stems and leaves of sedges and other plants; but being only about ½ to ¾ of a millimetre in length, and of an active disposition, it is a difficult object in the first place to see, and, in the next, to capture. It is most readily seen when on the water, and a good plan is to shake the plants and then drag the surface of the pool with a piece of black cloth—white, in this instance, is not so suitable.

The typical form, which is of a uniform red-violet colour, and is recorded only from Spitzbergen, Novaya Zemlya, and Behring Island, was described by Tullberg (17) in 1876. The striped form—to which all our specimens belong—was described as *Sminthurus elegantulus* by Reuter from Finland four years later. It is also recorded from Sweden, Russia, and Bohemia (Schött erroneously adds Germany and France —*cf.* Reuter's "Finlands Collembola," p. 13). Schäffer had not seen it prior to our sending him specimens. Folsom's *Sminthurus socialis*, described (4) from Massachusetts, U.S.A., in 1896, is evidently so very closely allied to our insect that its right to more than sub-specific rank may well be questioned.

The example from which our coloured figure was drawn, is one of the best marked we have seen: usually the dorsal marking is narrower, and the pale portions rather more yellow.

Local data.—On tiny pools, Bavelaw, near Balerno (Midlothian), 1st, etc., March, and April 1899, common; small pond, Bush, near Rosslyn (Midlothian), a few, 17th March; Otterston Loch (Fife), a good many, 18th March; Torduff Hill, Pentlands, and near Midcalder, a few, May; old flooded quarry, Longniddry (E. Lothian), Aug., common.

Sminthurus aquaticus, Bourl.

Locally common. Most of our specimens—all of the bluish or greenish white form, with purple antennæ and dark spot on forehead—are from a stagnant pool on the north side of the road through the Braid Hills, where the species

was met with in abundance among *Sparganium* and other water-plants in September 1897. Widely distributed in Europe, being on record from Norway, Sweden, Finland, Russia, Germany, England, Ireland, France, and Austria.

Local data.—Pool on the Braid Hills, Edinburgh, 20th Sept. 1897, abundant, and again on 5th May 1898; old marl pit, Davidson's Mains, near Edinburgh, 6th Aug. 1898, common; on surface of stagnant water in old quarry, Longniddry (E. Lothian), 30th Aug. 1898, a few; pond in Edinburgh Botanic Garden, Aug., abundant.

Sminthurus cæcus, Tullb., var. **attenuatus**, nov.

[Plate VII. Figs. 9-13.]

This small blind species occurs sparingly in the old subterranean limestone-quarry at Moredun, near Gilmerton, referred to more particularly under *Pseudosinella cavernarum.* We know of no previous record for Great Britain, but in Ireland the insect has been recorded by Carpenter (3) from the Mitchelstown Cave, Co. Tipperary. Abroad it has been found in or under flower-pots in Norway, Sweden, Finland, Russia, and Hamburg. Our Moredun examples agree with the type in being dotted over with minute red spots, which are absent in the specimen from the Irish cave, but they seem to differ from the type, as they do markedly from the Mitchelstown specimen, in the form of the mucro, which is straight, slender, and not clubbed (see Fig. 13): also the fourth antennal segment is longer than the other three together. Perhaps these structural differences are worthy of more than passing recognition: we therefore propose to designate the form var. *attenuatus.*

Local data.—Old limestone quarry or mine on Moredun Mains farm, near Gilmerton (Midlothian), one specimen secured on 12th April, and another on 18th April 1899. They were found on the under sides of stones which were slightly embedded in fine earth on the sloping floor of the dark portion of the quarry.

Genus **Papirius**, Lubbock.

Papirius cursor, Lubb.

Papirius fuscus, Lubbock's "Monograph."

With us this species, though not very common, seems to be pretty generally dispersed. Has been recorded from England,

but apparently not from Scotland till now. Its geographical range is known to extend from Siberia and Scandinavia to Ireland and Tunis.

Local data.—Morton, near Edinburgh, July 1896, two specimens; Braid Hermitage (Edinburgh), Oct. 1896, one; Ravelrig (Midlothian), Oct. 1896, several; Dreghorn (Midlothian), March 1897, two; Corstorphine Hill Wood, Oct. 1897, two; Bridge of Allan (W. Perth), Feb. 1898, half a dozen under pieces of bark lying on a wet mossy bank; Arniston (Midlothian), May 1898, one; Harburn, Oct., two; Ormiston fir-wood, near Kirknewton, fairly common under loose bark on fallen trees, May; banks of the Avon (Linlithgow), July, one.

Papirius ornatus (Nic.), Lubb.

[Plate VII. Figs. 14, 15.]

This form—the *P. ornatus* of Lubbock's "Monograph," and presumably the *Sminthurus ornatus* of Nicolet, since the former authority states positively that his insect is common in Switzerland—is abundant throughout our district under dead branches, etc., lying on wet grass or leaves, chiefly in or close to woods. Occurs at all seasons of the year, but especially from autumn to spring. It is doubtfully distinct (specifically) from the next, there being little or no difference between them except in colour and pattern, the shape of the dark marking (a central bar crossed by several shorter ones in *ornatus*, a squarish spot in *minutus*) on the hinder part of the abdomen being perhaps the readiest character by which to separate them. But both insects are subject to considerable variation in these respects, and we have met with specimens (pale ones) that might almost have been regarded as intermediate. *P. ornatus* is the common form in the British Isles generally, but elsewhere it seems only to have been recognised in Switzerland (as mentioned above), Germany, and Norway (6). Curiously enough, it is not mentioned in Reuter's Scottish list (12), and it is not known as yet in Sweden or Finland. Dr Reuter, to whom we have sent specimens, says it is not the same as the Continental *P. minutus*, var. *coulonii.*

Local data.—Bonaly (Midlothian), Feb. 1896; Dreghorn, Kirknewton, and Dalhousie, March; Colinton Dell and Mortonhall, abundant, April; near Aberlady, Aug., a few; Uphall, Sept.; Luffness Woods, Sept.;

Braid Hermitage, Rosslyn, Penicuik, and Ravelrig, Oct., common; Corstorphine Hill, Ratho, and St Margaret's, near N. Queensferry, Nov., common; Vogrie (Midlothian), Feb., and Dollar (Clackmannan), April 1897, common; near Kirkliston, Binny Craig, and Carribber Glen (Linlithgow), March 1898, a few; wood near Polton (Midlothian), April, many, of all ages, from the pale tiny young to the dark well-marked adults; Bridge of Allan, Feb. 1898, several, some small; Bucklyvie (Stirlingshire), April 1896, a few; Aberfoyle (W. Perth), April 1896, abundant; Dalmeny Park (Linlithgow), Feb. 1899, abundant; Aberdour (Fife), Feb., a few, of pale variety; etc.

Papirius minutus (O. Fabr.).

Papirius nigromaculatus, Lubbock's "Monograph."

Typical examples of this form, which appears to be much better known on the Continent than the last-mentioned, being on record for Norway, Sweden, Finland, Germany, Austria, Italy, Sardinia, etc., are by no means common about Edinburgh. In England it is, according to Lubbock, plentiful in Kent during the spring and summer months. In our experience it is more of a summer insect than *P. ornatus*, and frequents opener grassy places.

Local data.—Banks of Braid Burn below Comiston, end of July 1896 and 3rd Aug. 1898, a few along with the preceding; in garden, Morningside Park, Edinburgh, 17th and 18th July 1896, fairly common; Uphall, Sept. 1896, several, and Aberfoyle, a few; Torphin, March 1899, one; near Mid-calder, May, three; Inverkeithing, June, a few; Longniddry, Aug., one.

Family **ENTOMOBRYIDÆ.**

Genus **Tomocerus,** Nicolet.

Tomocerus plumbeus (Linn.).

Tomocerus longicornis, Lubbock's "Monograph."

Though common in England and Ireland, this species appears to be much less frequent in the Edinburgh district than some others of the genus. At any rate, we have as yet detected it in very few localities, and (apart from the structural differences revealed by the microscope) it is not difficult to recognise even in the field, by, among other things, its relatively pale leaden hue. Our common species, *T. tridentiferus*, for instance, has usually a decidedly darker

purple lustre about it. *T. plumbeus* has the antennæ much longer than the body, whereas in none of the three following forms do they exceed the body in length. The long filamentous inferior foot-claw, which is rather longer than the superior one, is also characteristic. On the Continent the present species is widely distributed—Norway and Sweden, Germany, Bohemia, etc., and it has also been recorded from La Plata.

Local data.—Buckstone, near Edinburgh, Feb. 1896, several; marshy spot near Longniddry (E. Lothian), Sept. 1897, a few; banks of Braid Burn below Comiston, 3rd Aug. 1898, common.

Tomocerus vulgaris (Tullb.).

Widespread and seemingly fairly common in this district, a fact of interest in view of the little that has hitherto been known of it as a British species. It is not mentioned in Lubbock's "Monograph," but Reuter (12) has recorded it from Shetland, and Brook (1) from Jersey. Apparently of northern distribution; it has been found in Sweden, Finland, Russia, Siberia, Germany, Bohemia, and the Tyrol. Like its congeners, it is to be looked for under stones, boards, bark, moss, etc. In living and unrubbed examples the colour is black or purplish-black, with bronze reflections.

Local data.—Pentland Hills above Boghall (Midlothian), several, and also near Swanston and East Calder, Feb. 1896; Mortonhall, Torduff Hill (Pentlands), and Kirknewton (Midlothian), March 1896; Gifford (E. Lothian), Sept. 1896, several; Duddingston Loch, Edinburgh, under boards among the reeds, March 1898, a few; Bavelaw, under logs, common, March 1899.

Tomocerus niger (Bourlet).[1]

Tomocerus flavescens (Tullb.).

[Plate VII. Fig. 16.]

This form is also widespread in the neighbourhood, and appears to be rather more common than the last. It is plentiful in England, but is not mentioned among Reuter's Scottish captures. On the Continent it ranges from Norway,

[1] Consult Reuter's paper (11) as to the nomenclature of this form.

Sweden, Russia, and Finland to France, Germany, Bohemia, Hungary, and Italy.

Lubbock (7) and Brook (1) state that this form is only to be distinguished from the next (*T. tridentiferus*) by its yellow colour when denuded of scales. We have, however, found specimens of *T. tridentiferus* whose body-colour is yellow; but the true *T. niger* differs from that species in well-marked structural characters. The spines on the dentes are simple, not tridentate; there are only two teeth on the upper claw of the foot (five or six in *T. tridentiferus*); and the lower claw is simple and tapering, not broadly lanceolate and toothed, like that of *T. tridentiferus.* The structural differences in the species of this genus have been well figured by Tullberg (16).

Local data.—Luffness, Aug. 1896, common; Gifford, Sept., a few; Uphall (Linlithgow), Sept., half a dozen; Ravelrig, Oct., several; Bavelaw Wood, near Balerno (Midlothian), April 1897, a few under bark of a dead fir lying in a damp spot; Longniddry (E. Lothian), Sept. 1897, common among wet moss in an old quarry; banks of Dalhousie Burn (Midlothian), March 1898, several.

Tomocerus tridentiferus (Tullb.).

Tomocerus plumbeus, Lubbock's "Monograph."
T. minor, Lubbock, Trans. Linn. Soc., 1862.

Very generally distributed, and by far the commonest species of the genus here. Common also in other parts of Scotland, in England, and in Ireland; but apparently much scarcer on the Continent, where it has been recorded only from Scandinavia, Finland, Germany, and Bohemia; it is likewise found in the Azores, and probably also in North and South America. Like its congeners, and so many other Collembolans, it occurs throughout the year—in winter as plentifully as in summer, for cold seems to have little or no effect on it—under stones, logs, etc., in all sorts of situations, provided they are not too dry.

Local data.—Arthur's Seat, Comiston, Colinton Dell, Torduff Hill, Balerno, Kirknewton, East Calder, and Dalhousie, Jan., Feb., March, and April 1896, abundant; Charlestown, Aberdour, and Kinghorn (Fife), Feb. and March, common; Bucklyvie, April, and Aberfoyle, May, plentiful; Longniddry, Feb., a few; Morton and Braid Burn, near Edinburgh, July,

common; Luffness and Isle of May, Aug., common; Swanston, Rosslyn, Penicuik, Corstorphine Hill, Sept. and Oct.; Abercorn (Linlithgow), Oct.; Ratho and N. Queensferry, Nov., common; Vogrie, Feb. 1897, abundant; Cullalo (Fife) and Dollar, April, plentiful; Balerno, June, several; North Berwick (E. Lothian), Aug., a few; Morningside, Oct., common under boards in garden; near top of Castle Law (Pentlands), and at Bridge of Allan, Feb. 1898; near Kirkliston, Binny Craig, and Carribber Glen (Linlithgow), March, common; etc.

Genus **Lepidocyrtus**, Bourlet.

Lepidocyrtus curvicollis, Bourl.

A very beautiful, and relatively long and narrow *Lepidocyrtus*, obtained in a greenhouse in the south side of Edinburgh, is referred by Dr Schäffer to this little known species. In life, the insect certainly looked quite different from any of the varieties of the next species (*L. lanuginosus*) that we have seen. From var. *fucatus*, which comes nearest to it in size, it differs structurally in having the dentes distinctly longer than the manubrium — in *fucatus* they are scarcely longer (Schäffer *in lit.*). Our specimens are 2½ to 3 mm. in length. Lubbock (7) has recorded the present form from England. On the Continent it seems to have been obtained only in France, Switzerland, and Russia.

Local data.—Under flower-pots in an old greenhouse, Newbattle Terrace, Morningside, Edinburgh, half a dozen examples, June 1899.

Lepidocyrtus lanuginosus (Gmel.), Tullb.

L. lignorum + *L. gibbulus* + *L. æneus*?, Lubbock's "Monograph."

This active little silvery-blue insect is extremely common throughout the district at all seasons of the year—almost every piece of wood, bark, stone, clod, and the like, beneath which there is a little moisture, when turned over, is found to shelter some. The underside of a decaying mushroom or other fungus is also a favourite haunt. Our specimens vary so much in size, and even in colour, without apparent reference to age, that we have sometimes found it difficult to believe that they all belong to one

species. We believe, however, that they intergrade. In any case we can find no structural differences sufficient to warrant their separation, and the best Continental authorities are apparently of the same opinion. The genus is admittedly one of the most difficult in the whole order, and much work will have to be done upon the life-histories of the various forms, before they are properly understood.

Besides the typical form, which is our common one, we have noted the following:—

1. Var. *fucatus*, Uzel. — Some of the larger specimens (length 2 to 2¼ mm.) sent to Professor Reuter and Dr Schäffer are referred by them to the form described by Uzel (18) under the name of *L. fucatus*, both authorities adding, however, that it is very likely only a variety of *L. lanuginosus.* Similar specimens sent to Dr Schött were named by him simply *L. lanuginosus.* Our own opinion is that they are co-specific, the relative lengths of the antennal segments being subject to considerable variation. Lubbock's figure of *L. lignorum* is suggestive of this variety.

2. Var. *albicans*, Reut.—A few small pale specimens sent to Dr Schäffer agree fairly well, in his opinion, with Reuter's *L. albicans*, though it is possible they are only young examples of the ordinary form. Having since received from Prof. Reuter true *albicans* (white with black frontal spot), we find we have occasionally obtained the form here.

3. Var. *minor*, nov.—a small brilliant metallic blue form, only about 1 mm. in length, with third antennal segment usually about two-thirds the length of the second one: body-colour pale whitish-yellow.—A colony of this form occurs under small stones scattered along the edge of a field at Comiston, near Edinburgh, and although the locality has been visited many times during the past six months, no larger examples have been found, so that their small size does not seem to be dependent on age. Professor Reuter, who has favoured us with a very full report on the *Lepidocyrti* submitted to him, suggests that this may perhaps be a new species. Dr Schött, however, names it *L. lanuginosus*, possibly a local variety; and Dr Schäffer also thinks it referable to *lanuginosus*, probably immature.

The species is a wide-ranging one—Siberia and Norway to Ireland, Austria, Italy, and Switzerland.

Local data.—Arthur's Seat, Dreghorn, Morningside, Torduff Hill, Colinton Dell, Balerno, Midcalder, Jan., Feb., March, and April 1896, many; Charlestown, Aberdour, Kinghorn, Feb. and March, common; Bucklyvie, April, and Aberfoyle, May, plentiful; banks of Braid Burn, Morton, etc., June and July, common; Aberlady, North Berwick, and Isle of May, Aug.; Rosslyn, Penicuik, Swanston Wood, Ravelrig, Corstorphine, Uphall, Abercorn, Ratho, North Queensferry, Sept., Oct., and Nov., common; Vogrie, Feb. 1897; Dalhousie, March; Cullalo and Dollar, April, many; Dalmeny and Bridge of Allan, Feb. 1898; Kirkliston, Binny Craig, and Carribber, March; Arniston and Kinross, May; Longniddry, Aug.; Lauder, Sept.; Edgelaw, Oct. Var. *minor:* Braid Hills, Feb. 1897, a few; Comiston, under stones on side of field, common, Oct. 1898 and onwards; Morton Mains, March, several. Var. *fucatus:* Aberdour, April 1897; Buckstone Farm, a good many under pieces of rotten wood in plantation, Nov. 1898 (named by Dr Schäffer); near Hillend Farm, March 1899, one (named by Professor Reuter). Var. *albicans:* Hillend, Pentlands, March, and Dalmahoy Hills, April 1899, a few under large stones.

Lepidocyrtus cyaneus, Tullb.

Lepidocyrtus purpureus + ? *L. violaceus*, Lubbock's "Monograph."

Not nearly so common as *L. lanuginosus*, but yet by no means rare. Though considerably smaller than normal examples of that species, it is not less beautiful, the colour being a more decided purple, with brilliant golden lustre—we refer, of course, to the living scale-clad insects. The body-colour, as seen in spirit-specimens, is usually uniform bluish or greyish black, but some are not so strongly pigmented, and occasionally an example with pale bands or other markings is met with. A specimen of the last-mentioned variety, submitted to Dr Schäffer, was referred by him to the var. *assimilis*, Reut. (= *L. violaceus*, Lubb. ?). Range very similar to that of the previous species, but there is no record south of the Tyrol.

Local data.—Garden at Morningside, Edinburgh, July 1896, Sept. 1897, and April 1898, common among loose earth and under boards; in garden at Aberlady, Aug. 1896, a few; Braid Hermitage, Dreghorn, Ravelrig, and Rosslyn, Oct. 1896; Liberton (Midlothian) and Longniddry (E. Lothian), Sept. 1897, on vegetable refuse; Thornton (Fife), Aug. 1898; Edgelaw, Oct.; Blackford Hill, March 1899, several (one of var. *assimilis*); Morningside, in greenhouses, April; Ormiston, Midcalder, small, very dark examples (typical *L. purpureus*, Lubb.), common under pieces of wood, April; etc.

Genus **Cyphoderus,** Nicolet.

Cyphoderus albinus, Nic.

Beckia albinos, Lubbock's "Monograph."

As yet we know of only one locality for this neat little silvery-white species; and there, as usual, it occurs in ants' nests. Although blind, it is very active. Ranges throughout Europe, and is recorded from N. America.

Local data.—At foot of Arthur's Seat, Edinburgh, fairly common under stones along with *Lasius flavus,* Oct. and Nov.

Genus **Pseudosinella,** Schäffer.

Pseudosinella cavernarum (Moniez).

Sira cavernarum, Moniez (9).
Cyphoderus Martelii, Carpenter (3).
Tullbergia immaculata, Lie-Pettersen (6).

On the farm of Moredun Mains, near Gilmerton, a few miles south of Edinburgh, there is an old limestone-mine or subterranean quarry, which there is reason to believe has not been worked for at least three-quarters of a century. The limestone beds—which are only a few feet thick and have a rapid dip—have not been quarried to any great depth, but in the line of outcrop the excavations extend fully a quarter of a mile. The line of outcrop is marked by a series of grassy and tree-girt hollows, from each of which at least one opening leads directly into the mine and admits more or less daylight. One portion of the mine —the southern—extends, however, probably 200 yards or more beyond the nearest present entrance, and in it traces of the outside light are soon lost. Here, on 11th April 1899, Evans spent several hours searching for Collembola, and was rewarded by the discovery of this interesting cave species, previously standing in the British list only from the Mitchelstown Cave in Ireland—see Carpenter's paper (3) in the *Irish Naturalist* for 1897, where full particulars, with description and figure of the insect, which is white and destitute of eyes, are given. The Moredun examples are quite indistinguishable from Mitchelstown ones. The type specimen was obtained by

Prof. Moniez in the deepest part of the great cavern of Dargilan, in the south of France (9).

How this typical cave-species comes to be in so comparatively shallow and recent an excavation as the quarry at Moredun, is a rather perplexing problem. The idea of recent independent development there is out of the question. In all probability it existed in holes and crevices in the rocks ages before the quarry was begun.

[Since the above was written, Dr Schäffer, having seen one of our specimens, has drawn our attention to the apparent identity of our insect with the *Tullbergia immaculata* of Lie-Pettersen, recently described (6), from Norway, where it occurs under stones among loose earth in cultivated places.[1] Irish examples of our insect having been pronounced by Professor Moniez the same as his *Sira cavernarum*, we feel bound to accept his identification.]

Local data.—Old limestone-mine, Moredun Mains, near Gilmerton (Midlothian), fairly common under stones in April and May 1899.

Genus **Seira**, Lubbock.

Seira buskii, Lubb.

Occurs sparingly under or about flower-pots in greenhouses in the Morningside district of Edinburgh, and doubtless in like situations in a number of other localities; but we have not yet discovered any outdoor habitat for it. This, however, does not necessarily imply that it is a foreign importation, for along with it we find truly indigenous species, such as *Tomocerus tridentiferus*, *Entomobrya multifasciata*, and *Lipura armata*.

Its known range extends from Scandinavia to Italy, and from England to Hungary and even Siberia.

Local data.—Greenhouses, Morningside, Edinburgh, February, March, and April 1899, about a dozen specimens.

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[1] A specimen of the Norwegian insect has since been kindly sent to us by Mr Lie-Pettersen: it is undoubtedly of the same species as our insect. The generic name (*Pseudosinella*) proposed by Schäffer (14) in place of *Tullbergia* (preoccupied) has priority over that (*Pettersenia*) proposed by Scherbakow ("Zoologischer Anzeiger," 1898). We think it very likely that this species may ultimately prove to be *Beckia argentea*, Lubb.

Genus **Entomobrya**, Rondani (= **Degeeria**, Nicolet).

Entomobrya albocincta (Templ.).

Degeeria cincta, Lubbock's "Monograph."

This well-marked Spring-tail is fairly common around Edinburgh, under stones on wall-tops, loose bark on old trees, etc. It is not so dependent on moisture as the majority of the order, and is more frequently than not found in dry situations. Found throughout the British Isles (to Ireland and the Shetlands), but apparently dying out on the Continent, being only recorded from Scandinavia, Germany, and Bohemia. It is said to occur, however, in South America (La Plata).

Local data.—Fairmilehead (Midlothian), July 1896, and again in April 1898, a few under stones on wall-top; Comiston (Midlothian), July 1896, several under bark on dead beech; Rosslyn, Oct. 1896; Braid Hills, Nov. 1896 and April 1897, a few; Macbiehill (Peeblesshire), Feb. 1896, three; Balerno, June 1897, a few; Polton, April 1898, a good many under bark on dead silver fir; Swanston Wood (Pentlands), under bark, common, May 1898; Morningside, in greenhouses, common, June; Lauder, Sept., a few.

Entomobrya nivalis (L.).

Degeeria annulata, Lubbock's "Monograph."

Very common and widespread, occurring in a variety of situations and at all seasons. By beating the lower branches of trees, furze and other bushes, heather, thistles, ferns, etc., over an umbrella, large numbers can usually be obtained during the spring and summer months. It is also of frequent occurrence under bark, etc., such situations being probably those to which it resorts for the purpose of depositing its eggs. When in life typical examples have a greenish-grey appearance. Ranges through Europe from Scandinavia and Finland to Ireland, France, and the Tyrol; and occurs also in North America.

Local data.—Torduff Hill and Hillend (Pentlands), and also in Colinton Dell, common under stones, March and April 1896; abundant on young spruce trees near Rosslyn, July 1893; Mortonhall (Midlothian), July 1896, etc.; Aberlady and Yester (E. Lothian), Sept., Uphall, Pentland Hills above Bavelaw and Currie, common on thistles and heather, and near Dun-

Genus **Templetonia,** Lubbock.

Templetonia nitida (Templ.).

Templetonia crystallina, Lubbock's "Monograph."

Occurs sparingly under stones, boards, etc., embedded in or lying on damp earth, doubtless in most parts of the district, but as a rule it is not common. Ranges throughout Europe.

Local data.—Morton Mains, July 1896, three; and again in Oct. 1897, two specimens; East Linton (Haddingtonshire), Nov. 1896, common about the roots of celery; Braid Hills, April 1897, two; and Buckstone, near Edinburgh, June, one; Mortonhall, 20th April 1898, two; Arniston, 12th May, two; under board in garden at Morningside, Edinburgh, 14th Oct., common. Craigentinny Meadows, Feb. 1899; Burntisland, March; Linlithgow, Aug.; Lauder, Sept.

Genus **Isotoma,** Bourlet.

Isotoma viridis, Bourl.

Isotoma anglicana + ? *I. viridis* and *I. viatica*, Lubbock's "Monograph."

[Plate VII. Fig. 17.]

Throughout the entire district, and throughout the year, this rather variable species is present in abundance, dozens being often found together in such situations as the under side of a piece of old fence-rail, or a half-rotten turnip lying on damp grass or earth. The typical dark, sooty, or purplish-green form is the prevalent one, but much greener examples and also yellowish-brown ones are by no means uncommon; others much resembling the darker of Schött's figures of the var. *riparia*, Nic., likewise occur occasionally. The species ranges from Spitzbergen and Siberia to the Tyrol, France, and Ireland, occurring also in North America.

Local data.—Swanston, Castlelaw, and other localities on the Pentland Hills, Feb., March, and April 1896, common; Comiston, East Calder, Macbiehill, and Longniddry, Feb.; Dreghorn, Balerno, Aberdour, and Kinghorn, March; Bucklyvie and Loch Ard, April and May; Mortonhall, March and July, common; Aberlady, August, a few; Uphall, Sept.; Rosslyn and Penicuik, common, Oct.; Ratho, Corstorphine, and North Queensferry, Nov.; Vogrie and Kirknewton, Feb. 1897; Dollar and Cullalo (Fife), April, common; Isle of May, Aug.; Longniddry, Sept., var. *riparia*, with type; Carlowrie and Carribber Glen, March 1898; Dalhousie, March; Kinross, May; Bush, near Rosslyn, type and var. *riparia*, March; etc.

Brook (2) regards the three last named forms as varieties of one species. We are inclined, however, to follow Reuter, Tullberg, Schäffer, Schött, and others, in considering them distinct.

Local data.—Among vegetable refuse in a garden at Aberlady, East Lothian, Aug. 1896, a few; in greenhouse, Morningside, March 1899, one.

Genus **Orchesella,** Templeton.

Orchesella cincta (Linn.).

This, in some respects the finest of our Spring-tails, is both common and generally distributed in the district. Although occurring throughout the year, we have found it more numerous from autumn to spring than during the summer. The three varieties so beautifully figured in Lubbock's "Monograph" have all been met with: the pale one, however, is rare. The dark form is the var. *vaga*, Linn. The species ranges throughout Europe, occurring also in North America and Greenland.

Local data.—Fairmilehead and North Berwick, Jan.; Arthur's Seat, Comiston, Pentland Hills above Swanston, and Burntisland, under stones, bark, etc., type and var. *vaga*, Feb.; Mortonhall, Balerno, and Kirknewton, March; Bucklyvie and Aberfoyle, April; Comiston, July; Longniddry, Aug.; Luffness and Uphall, Sept.; Rosslyn and Penicuik, Oct.; and Ratho, Nov.—all in 1896; Vogrie, Feb.; Braid Hills, Cullalo, and Dollar, common, April 1897; Arniston, May; and banks of Braid Burn, a few, June 1898; etc.

Orchesella villosa (Geoff.).

We have as yet met with *O. villosa* in but two localities, both in the western outskirts of the district. It is evidently very local, and probably nowhere common. This appears to be a more or less southern species; for though Lubbock states that it occurs in Sweden, it is not mentioned in any of the Scandinavian or Finnish lists of Tullberg, Schött, Lie-Pettersen, and Reuter. It is recorded from Germany, France, Switzerland, and England, and is found in Ireland.

Local data.—Bridge of Allan (W. Perth), Jan. 1894, a few; Dollar (Clackmannanshire), April 1897, a good many under stones at foot of a hedge.

Genus **Templetonia,** Lubbock.

Templetonia nitida (Templ.).

Templetonia crystallina, Lubbock's "Monograph."

Occurs sparingly under stones, boards, etc., embedded in or lying on damp earth, doubtless in most parts of the district, but as a rule it is not common. Ranges throughout Europe.

Local data.—Morton Mains, July 1896, three; and again in Oct. 1897, two specimens; East Linton (Haddingtonshire), Nov. 1896, common about the roots of celery; Braid Hills, April 1897, two; and Buckstone, near Edinburgh, June, one; Mortonhall, 20th April 1898, two; Arniston, 12th May, two; under board in garden at Morningside, Edinburgh, 14th Oct., common. Craigentinny Meadows, Feb. 1899; Burntisland, March; Linlithgow, Aug.; Lauder, Sept.

Genus **Isotoma,** Bourlet.

Isotoma viridis, Bourl.

Isotoma anglicana + ? *I. viridis* and *I. viatica,* Lubbock's "Monograph."

[Plate VII. Fig. 17.]

Throughout the entire district, and throughout the year, this rather variable species is present in abundance, dozens being often found together in such situations as the under side of a piece of old fence-rail, or a half-rotten turnip lying on damp grass or earth. The typical dark, sooty, or purplish-green form is the prevalent one, but much greener examples and also yellowish-brown ones are by no means uncommon; others much resembling the darker of Schött's figures of the var. *riparia,* Nic., likewise occur occasionally. The species ranges from Spitzbergen and Siberia to the Tyrol, France, and Ireland, occurring also in North America.

Local data.—Swanston, Castlelaw, and other localities on the Pentland Hills, Feb., March, and April 1896, common; Comiston, East Calder, Macbiehill, and Longniddry, Feb.; Dreghorn, Balerno, Aberdour, and Kinghorn, March; Bucklyvie and Loch Ard, April and May; Mortonhall, March and July, common; Aberlady, August, a few; Uphall, Sept.; Rosslyn and Penicuik, common, Oct.; Ratho, Corstorphine, and North Queensferry, Nov.; Vogrie and Kirknewton, Feb. 1897; Dollar and Cullalo (Fife), April, common; Isle of May, Aug.; Longniddry, Sept., var. *riparia,* with type; Carlowrie and Carribber Glen, March 1898; Dalhousie, March; Kinross, May; Bush, near Rosslyn, type and var. *riparia,* March; etc.

Isotoma palustris (Müll.).

Isotoma palustris + *I. aquatilis*, Lubbock's "Monograph."

[Plate VII. Figs. 18, 19.]

This is another widespread and abundant insect, especially among herbage in marshy places, and by the margins of pools and ponds. The typical form—upper surface pale yellowish-green, with one or three dark longitudinal stripes—is the common one here; but we have also the following varieties, viz.:—var. *prasina*, Reut. (entirely yellow-green), and what seems to be var. *fucicola*, Reut. (uniform violet-brown). Specimens agreeing with var. *aquatilis* (Müll.), as figured by Schött (15), have also occasionally been found on pools along with the type. A beautifully marked form (Pl. VII. Fig. 18), with the *palustris* foot and mucro, which Dr Schäffer tells us (*in lit.* 20/2/99) is his var. *maculata*, is common in gardens and greenhouses. We can see practically no difference between it and the *I. aquatilis* of Lubbock's "Monograph," except that in the latter the spots along the back are more extensive, and form a distinct dorsal stripe. Both have a few long abdominal hairs, the *absence* of which is apparently considered by Schött to be a character of *I. palustris* and its varieties. The difference in habitat between this form and true *palustris* is also noteworthy.

Range exceedingly wide, and very similar to that of the last-mentioned species — Novaya Zemlya and Siberia, to Italy, Ireland, the Azores, California, La Plata (Parona), and Bismarck Archipelago (Schäffer).

Local data.—Pools on Bavelaw Moss, March, and Threipmuir Pond, April 1896, abundant; pond on top of the Braid Hills, and small marsh lower down, common, July 1896, April and Sept. 1897, etc.; Luffness Marshes, Aug. 1896; Uphall, Sept.; Ravelrig, Oct.; Loch Ard, April; Gartmorn Dam (Clackmannan), and reservoir near Cullalo (Fife), April 1897; Isle of May, Aug.; quarry-hole near Longniddry, Sept., type and variety *aquatilis* (Müll.); Loch Leven, May 1898; Edgelaw Reservoir (Midlothian), Oct.; Otterston Loch, March 1899. Var. *fucicola:* Bavelaw Bog, June 1897, March 1899, etc., common. Var. *prasina:* Craigentinny Meadows, Jan. 1899, a good many; Bush, near Rosslyn, March, one; Bavelaw Bog, May, a few. Var. *maculata:* in gardens at Morningside and Aberlady, Sept. 1896, June 1898, etc., common on borders and gravel walks, and under flower-pots in greenhouses; banks of Dalhousie Burn, March 1898; etc.

Isotoma maritima, Tullb.

[Plate VII. Figs. 20-22.]

Locally common on decaying wrack (*Fucus,* etc.) on the shores of the Firth of Forth. Specimens from the Dalmeny beach are much larger than a series from the Fife coast at Aberdour (length, $2\frac{1}{4}$ to $2\frac{1}{2}$ mm., as against $1\frac{1}{2}$ to $1\frac{3}{4}$ mm.); but structurally they are the same. Identification confirmed by Drs Schött and Schäffer.

Schött (15) suggests that perhaps Lubbock's *I. grisea* is identical with the present form. The description (second antennal segment longer than third, etc.) seems to us, however, to agree better with that of Schäffer's *I. grisescens.*

I. maritima is recorded from Sweden, Finland, Germany, and Bohemia.

Local data.—Dalmeny beach (Linlithgowshire), on cast-up *Fucus,* etc. (wrack), a few specimens on 31st Dec. 1898, and about thirty on 14th Feb. 1899; Aberdour (Fife coast), on rotting wrack, fairly common, 11th Feb.

Isotoma grisescens, Schäffer.

? *Isotoma grisea,* Lubbock's "Monograph."

[Plate V. Fig. 4; Plate VII. Figs. 23-25.]

Widely distributed, but as a rule not very common, among dead leaves and under bark on old trees lying in damp woods; also among moss, etc. It has not previously been recorded from the British Isles, unless it is the same as Lubbock's *I. grisea* (from Kent?), which appears to us not improbable.[1] We have found the species in Ireland.

This form was described (13) from examples taken near Hamburg by Dr Schäffer, who has kindly examined and identified some of our specimens. It is intermediate between *I. olivacea,* Tullb., and *I. violacea,* Tullb.—two closely allied northern species, for mounted specimens of which we are indebted to Dr Schött—agreeing with the former in the short, even nature of its hairy covering with little or no trace of outstanding bristles, but with the latter, as it seems

[1] In a recent paper (8) Sir John Lubbock treats *I. grisea* as having only two teeth on the mucro, but we can see nothing to this effect in his original description of the insect, either in *Trans. Linn. Soc.* or in the "Monograph."

to us, in the form of its feet and mucro.[1] Both claws of the front feet are without teeth; the upper claws of the second and third feet are sometimes, and the lower ones usually, toothed. The colour is bluish olive-grey, some examples being considerably paler than others; none, however, are so yellow-olive as *olivacea* on the one hand, or so violet-black as *violacea* on the other. Dr Schött, to whom we have also sent specimens of this Spring-tail, indeed considers it probably a pale variety of *I. violacea,* Tullb. (*in lit.* 1/5/99), and it will be seen that his figures (15) of the foot-claws and the mucro agree closely with those of our insect (Figs. 24, 25). But Prof. Reuter, who has likewise seen some of our specimens, considers them more nearly related to *I. olivacea* than to *I. violacea.* "Sie sind," he writes, "was ich in Coll. Fenn. als *I. olivacea var.* bestimmt habe." According to Dr Schäffer, the post-antennal organ of *I. grisescens* (Fig. 23) is relatively longer and narrower than that of *I. violacea,* and like that of *I. olivacea.* It is possible that further research will force us to consider all three forms as varieties of a single species.

Local data.—Ravelrig, several among dead leaves, 16th Oct. 1896; Flotterston, near Penicuik, a few among moss, 20th Oct.; Swanston Wood, several in moss, 28th Oct.; Hallyards, near Ratho, half a dozen under moist bark on remains of old tree, 10th March 1898; Dalhousie, a good many under bark, 19th March; Mortonhall, on fallen boughs, a few, Dec., and again in March 1899, common among leaves; Craigentinny Meadows, under pieces of wood, common, Feb.; Bush, near Rosslyn, March; near Midcalder, May.

Isotoma sensibilis, Tullb.

Isotoma denticulata, Schäffer (13), and (?) *I. dubia,* Reuter (11).

[Plate V. Fig. 5; Plate VII. Figs 26, 27.]

Specimens of a small purplish *Isotoma* collected at many localities around Edinburgh belong, according to Drs Schött and Reuter (who have kindly examined some of them), to this species. Our Scotch examples have, like typical *I. sensibilis,* two tenent hairs on each front foot, and three on each intermediate and hind foot. The lower claw in our specimens

[1] Dr Schäffer points out to us that, owing to a mistake on the part of the engraver, the mucro of his insect is figured (13) with a tooth too few.

shows, however, a small but distinct tooth (Fig. 26), and the mucro has in most cases four teeth (Fig. 27), agreeing exactly in form with that of *I. denticulata,* Schäffer (13). Dr Schäffer also kindly examined some of our specimens, and at first referred them to the latter species. He has since informed us (*in lit.* 15/1/99) that he has detected differences, but a comparison of the Edinburgh insects with Hamburg specimens, courteously communicated by him, leads us unhesitatingly to agree with his earlier opinion. In *I. denticulata* three tenent hairs are said to be present on all the feet, but, as Dr Schäffer has himself informed us, this character is not constant. As some of our specimens (like one of those from Hamburg) show the three-toothed mucro of typical *I. sensibilis* (the small ventral tooth of Fig. 27 being absent), we have no hesitation in referring the whole of them to that species, and considering the form of the mucro not to be a constant specific character. We believe, therefore, that neither *I. denticulata,* Schäffer, nor *I. dubia,* Reuter (11)—the latter founded on a single individual—can be specifically distinguished from *I. sensibilis.*

This small Spring-tail is widely dispersed in the district, and where found it is usually plentiful. Its favourite habitat is under damp bark on fallen trees that are far advanced in decay. A ready way of finding it is to beat pieces of the bark over a sheet of white paper. When alive, the usual colour is dark purple with green reflections.

I. sensibilis was described by Tullberg (17) from Novaya Zemlya, and it has been recorded from Finland, Sweden, Norway (whence we have a typical example kindly sent us by Mr Lie-Pettersen), and Germany; it also occurs in Ireland. That it should have remained so long unnoticed in this country is somewhat singular.

Local data.—Abercorn (Linlithgow), 1st Oct. 1896, one specimen; Vogrie Glen (Midlothian), 27th Feb. 1897, abundant under bark on old tree stump; Cullalo (Fife), 3rd April, plentiful under bark on prostrate and decayed fir; Dollar, April, a few; Bridge of Allan (S.W. Perth), Feb., a few under bark lying on a wet bank; Hallyards, near Kirkliston, March, abundant in usual situation; Dalhousie, March, several; Swanston Wood, May and Nov., common; Dalmeny Park, Dec.; near Rosslyn, March, common; Kirknewton, May, a good many, some dark greenish-grey.

Isotoma cinerea (Nic.).

[Plate VIII. Figs. 1, 2.]

We have not met with this inconspicuous form often, but it will yet be found, no doubt, in most parts of the district. Beyond the limits of our present area we have collected it near Comrie, in Mid-Perth. Prof. Reuter kindly named some of our first specimens for us, and others have since been examined by Dr Schäffer. The fourth or ventral tooth of the mucro (Fig. 2) is sometimes only slightly developed, or even absent altogether.

The species is common on the Continent, ranging from Scandinavia and Finland to France, Italy, Bohemia, and Hungary, and it has also been brought from Siberia. Schött is evidently in error in supposing it has been recorded from England by Lubbock.

Local data.—Cullalo (Fife), 3rd April 1897, common under moist bark on a dead spruce; Dreghorn (Midlothian), Feb. 1898, many under bark on old logs; Bush, near Rosslyn, March 1899, a few under bark on fir logs.

Isotoma fimetaria (Linn.), Tullb.

[Plate VIII. Figs. 3, 4.]

Common under flower-pots and boards in gardens and greenhouses: occurs also, though much less frequently, under fallen branches, etc., in the open country. Dr R. S. MacDougall has sent us a great many, obtained amongst sawdust at the Edinburgh Botanic Garden.

On the Continent this small whitish species ranges from Norway to Bohemia; and it is also known from Siberia, Franz Josef Land,[1] and Greenland. It appears to be an addition to the British list.

Local data.—Beneath flower-pots in greenhouses, Morningside, Feb. and April 1899, common; under pieces of wood on Craigentinny Meadows, near Edinburgh, Feb.; and on a dead branch lying on the edge of a field, Lawhead Farm, Midcalder, May, a few; Botanic Garden, Edinburgh, March, swarms amongst sawdust.

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[1] A paper on the Collembola collected by the Jackson-Harmsworth Expedition in Franz Josef Land is now in preparation by Carpenter.

Isotoma spitzbergenensis, Lubb.

[Plate VIII. Figs. 5-8.]

Half a dozen specimens clearly referable to this species, described only last year (1898) by Lubbock (8) from Spitzbergen, were obtained on the beach at Dalmeny, a few miles west of Edinburgh, in January 1899. They were found by shaking bunches of rotting wrack (*Fucus*) over a sheet of white paper, and were fairly common, but, owing to their minuteness and agility, it was no easy matter to secure them. A month later it was met with rather plentifully on other parts of the shores of the Firth of Forth.

The long terminal and two upright basal teeth to the mucro (Fig. 8) readily distinguish the species, which is rather nearly allied to *I. schötti*, D. T., and *I. crassicauda*, Tullb., both characteristically northern and arctic forms. The types of this Spring-tail were collected at Dickson Bay, Spitzbergen, in July 1896. It forms an interesting addition to the British fauna.

Local data.—Beach at Dalmeny Park, Linlithgowshire, fairly common on cast-up wrack, 10th Jan. 1899; Musselburgh (Midlothian) and Cockenzie (E. Lothian), common on wrack, 9th Feb.; S. Queensferry, common, 14th Feb.; Aberdour, two, 11th Feb.

Isotoma schötti, Dalla Torre.

Isotoma litoralis, Schött (*nec* Moniez).

[Plate V. Fig. 6; Plate VIII. Figs. 9, 10.]

This is another characteristically northern *Isotoma*, which we have obtained off rotting wrack on the southern shore of the Firth of Forth, the locality in this instance being on the beach between Leith and Portobello, where a few specimens were secured in January 1899. [We have since (in Sept.) found it in abundance on the surface of water at Methven Bog, near Perth, an inland locality.]

The species was described in 1893 by Schött (15), who had examined specimens from Spitzbergen, Sweden, and Finland. Schäffer (13) obtained it from the mouth of the Elbe, and Carpenter ("Proc. Dublin Micro. Club," in *Irish Naturalist*, vol. vii., 1898, p. 54) recorded it last year from

the west coast of Ireland. It is very closely allied to *I. crassicauda*, Tullb., which has been recorded from Shetland by Reuter (12), but may be readily distinguished by the less robust dentes and less pointed mucrones of its spring (Fig. 10). Schött's name being preoccupied, Dalla Torre has renamed the species after its discoverer. The colour is described as "rotbraun" by Schött, but in our specimens it varies from brownish-violet to blue-violet: colour, however, is a very uncertain character in this group.

Local data.—Craigentinny beach between Leith and Portobello, a few, along with *Achorutes viaticus*, on rotting wrack, 14th Jan. 1899.

Family **PODURIDÆ.**[1]

Genus **Podura,** Linnæus.

Podura aquatica, Linn.

Locally common on the surface of stagnant water. As yet we have met with it only in East Lothian. It occurs commonly in England and Ireland, and abroad it is a species of the widest range—Siberia, all Europe, Greenland, and North America.

Local data.—Gullane, Aug. 1896, abundant on surface of water in old quarry; Longniddry, Aug. 1898, in some numbers in a similar situation.

Genus **Xenylla,** Tullberg.

Xenylla humicola (O. Fabr.), Tullb.

Achorutes humicola, Lubbock's "Monograph."

[Plate VIII. Figs. 11-14.]

Occurs locally among rotting wrack on both shores of the Firth of Forth. Drs Schött and Schäffer have kindly examined some of our specimens, and concur in referring them to this form, hitherto known only from Greenland, Behring Island, Novaya Zemlya, Finland, and North-West Germany. The colour is a nearly uniform bluish or purplish black. The very closely allied form, *X. maritima*, Tullb., has been recorded from Jersey by Brook (1), and Carpenter has obtained it from the coast of Ireland.

[1] = Schött's Lipuridæ.

Local data.—Dalmeny beach (Linlithgow), on rotting wrack, 31st Dec. 1898, half a dozen specimens; and at Aberdour (coast of Fife), also on rotting wrack, 11th Feb. 1899, three.

Genus **Achorutes,** Templeton.

Achorutes armatus (Nic.).

This pretty little Spring-tail is widely distributed, and rather common in the district, occasionally appearing in large numbers on putrid vegetable matter. Schött states that it has been recorded from England by Lubbock, but there is nothing in the latter's "Monograph" to that effect, though his remarks in *Trans. Linn. Soc.*, 1868, might perhaps be so interpreted.

A very widely distributed species—Siberia to Ireland and Italy, Greenland, North and South America, Sumatra.

Local data.—Aberlady, Aug. 1896, one specimen; Rosslyn, Oct., a few under cow-dung; North Berwick, Aug. 1897, one; Bridge of Allan, Feb. 1898, fairly common in moss; Hallyards, near Kirkliston, March, half a dozen under bark on rotten tree; Edgelaw, Oct., a good many under pieces of wood lying on grass; Dalmeny beach, on putrid wrack, Dec., very abundant; Morningside, on rotten hyacinth bulbs, Feb. 1899, abundant; Comiston, on rotten turnips, March, common.

Achorutes longispinus, Tullb., var. **scoticus,** nov.

[Plate V. Fig. 7; Plate VIII. Figs. 15-18.]

A dark blue-grey *Achorutes*, agreeing well with *A. longispinus*, Tullb., in the main structural features, occurs sparingly among wet moss (*Sphagnum*) on Bavelaw Bog, at the foot of the Pentland Hills. As Dr Schäffer, to whom we are indebted for Spitzbergen examples of the species, points out, however, the dorsal bristles of the latter are not so long as in our insect, which we would add has also a more mottled appearance, and has the anal spines bent more forwards (Fig. 16). Although of secondary importance, these differences have doubtless some significance, a fact we have thought it advisable to emphasise by naming our insect var. *scoticus*.

A. longispinus was described from Novaya Zemlya by Tullberg (17) in 1876. It inhabits Franz Josef Land,

and Schäffer (14) has recently recorded it from Spitzbergen and Buenos Ayres.

Local data.—Bavelaw Moss, near Balerno (Midlothian), in wet *Sphagnum*, 1st and 13th March 1899, a dozen specimens.

Achorutes viaticus (Linn.), Tullb.

Achorutes murorum + *A. dubius?*, Lubbock's "Monograph."

Has been met with in widely separated parts of our area: occasionally appears in immense numbers both on the sea margin and inland. It seems to be in the main a northern species, only extending its range southwards along the ocean coasts. It is recorded from Siberia, Spitzbergen, Greenland, Norway, Russia, Denmark, Hamburg, Britain, Behring Island, and California; and recently from Strait of Magellan and Tierra del Fuego.

Reuter (12) found this species in Orkney and Shetland, and recorded it as new to the British Isles, but if it be identical with Templeton's *A. dubius*, it has been long known both in Ireland and England.

Local data.—Aberlady Bay, Sept. 1896, in immense numbers on the sands for a distance of several hundred yards on the east side of the bay towards Gullane Point—in some places there could not have been less than 20,000 to 30,000 in the space of a square yard, so that they were literally present in millions. Musselburgh, Feb. 1897, half a dozen in moss off wall; Comiston Road, south of Edinburgh, 11th Nov., great numbers on top of wall adjoining a newly manured field; Longniddry, Aug. 1898, a good many in wet hollow on the links; Colinton Road, west of Edinburgh, 6th Oct., very abundant on wall-top; Craigentinny beach, Jan. 1899, common on wrack; South Queensferry, on wrack, Feb., a few; Comiston, on putrid turnip, March, several.

Achorutes purpurascens, Lubb.

Widely distributed in our area, having been met with in a number of scattered localities; but it appears to be nowhere very common. Probably widely spread over Europe—Sweden and Finland to Italy, Hungary, and Great Britain. Recorded also from the southern extremity of South America.

Local data.—Colinton, Oct. 1896, one specimen; Braid Hermitage, same month, one among dead leaves; Dollar, April 1897, two on dead branch lying on the ground; Dreghorn, Feb. 1898, a few under bark; Bridge of Allan,

same month, one under bark; Ratho, March 1898, half a dozen in moss off wall; Craigentinny Meadows, on pieces of wood, Feb. 1899, common; Otterston Loch, March, a few floating on surface of the water.

Achorutes manubrialis, Tullb.

Only recognised as yet in a single locality, as mentioned below. We know of no other record of the species for the British Isles except that of Brook (1), who found it in Thanet in October 1880. Abroad it is recorded from Sweden, Finland, Germany, and South America.

Local data.—Morton, near Edinburgh, 8th and 10th March 1899, a few on the under sides of stones lying on earth by the roadside.

Achorutes rufescens (Nic.).

[Plate V. Fig. 8; Plate VIII. Figs. 19-22.]

We have, as yet, found this form in but two localities in the district: from its small size it is, however, easily overlooked. Lubbock (7) records it from England, but does not figure it.

Apparently a rare species of discontinuous range. Recorded only from Sweden (by Tullberg, but queried by Schött), Switzerland, and Great Britain.

Local data.—Braid Hermitage, one specimen among dead leaves, 15th Oct. 1896; Longniddry, fairly common on rotting cabbage leaves, 28th Sept. 1897.

Genus **Triæna**, Tullberg.

Triæna mirabilis, Tullb.

[Plate VIII. Fig. 23.]

It is a source of no little satisfaction to us to be able to include this most interesting form in our list. Tullberg, who first described the species (16), found his specimens under pieces of wood in a cattle-yard, and among cast-up seaweed in Sweden, and it has since been got by Brook (1) under boards in a garden in England. We know of no other records. Our specimens—about a score—were found floating, to all appearance in a helpless condition, on the surface of a stagnant ditch leading from a small marsh on the

Pentland Hills, and had, we presume, been flooded out of the moss by recent heavy rain.

T. mirabilis is a minute pale blue-grey species, the sole representative of a genus characterised by, among other things, the very rudimentary nature of the spring. Tullberg's figures of it are reproduced in Brook's paper.

Local data.—Tordnff Hill, Pentlands, May 1899, a good many floating on surface of stagnant water in a deepish ditch.

Genus **Anurophorus,** Nicolet.

Anurophorus laricis, Nic.

Lipura corticina, Lubbock's "Monograph."

Locally common, but it is a species we have not met with very often here. It seems less dependent on moisture than many other Spring-tails; nevertheless we have found it in wet *Sphagnum* in a bog. Distributed throughout Europe, and recorded from Siberia.

Local data.—Duchray (Stirlingshire), April 1896, common under bark on dead but standing larch; Dreghorn, near Edinburgh, Feb. 1897, common on dead larch branches lying on the ground; Swanston Wood, March, a few under bark; Dalhousie, March 1898, on dead branches; near Kinross, May, abundant under top stones of a wall close to Loch Leven; Bavelaw Bog, March 1899, two small examples out of wet *Sphagnum;* near Kirknewton, May, common on dry cow-dung.

Genus **Lipura,** Burmeister (=**Aphorura,** A. D. MacG.).

Lipura armata, Tullb.

Lipura armata + ? *L. Burmeisteri,* Lubbock's "Monograph."

Widely distributed, and common under boards, stones, flower-pots, etc., lying on damp earth or grass. Only to be distinguished from the next form, so far as we can make out, by the number of prominences in the post-antennal organ (say twenty-five to thirty against twelve to fourteen), and the number of pseudocelli (three instead of two) at the base of each antenna.

Judging by the description and figures, Lubbock's *L. burmeisteri,* found under boards in England, was probably

this form, which is common in North and Middle Europe, and has also been recorded from Greenland, Siberia, and Chili.

Local data.—Swanston, March 1896; Bavelaw, under stones and pieces of wood, March 1897, etc., common; Mortonhall, May, common; North Berwick, Aug.; Carribber, March 1898; Edgelaw, Oct.; Buckstone, Nov.; Craigentinny Meadows, under logs, Feb. 1899, abundant; Morningside, under boards and flower-pots in gardens and greenhouses, Feb., March, and April, common; Aberdour, Feb., a few; etc.

Lipura ambulans (Linn.), Tullb.

Widely distributed and apparently common, but to separate it from the previous form entails a very careful microscopical examination of every specimen: occurs chiefly among damp earth and leaves, and on the under sides of stones and pieces of wood lying on damp ground. Probably ranges throughout Europe—Dr Schäffer, however, tells us he has not yet found it in Germany.

Local data.—Arthur's Seat, and near East Calder, Feb. 1896; Dreghorn, March; Comiston, July, a few; Gladsmuir, Sept.; Braid Hermitage, Oct., under dead leaves; Rosslyn, Abercorn, North Queensferry, Oct. and Nov., Vogrie, Feb. 1897; Balerno, two, Aberdour, a few, Dollar, April; Bridge of Allan, Feb. 1898; Whitehill (Midlothian), Binny Craig, March; Mortonhall, March 1899; Morningside, in greenhouse, March; Moredun limestone quarry, April, several.

Lipura fimetaria (Nic., 1847), Lubb.

Lipura inermis, Tullb.

[Plate VIII. Fig. 24.]

This species is common under flower-pots, etc., in gardens and greenhouses in the southern suburbs of Edinburgh, and no doubt in many other localities in the district. Drs Schäffer and Folsom (5) have recently come to the conclusion that *Lipura fimetaria*, Lubb., and *L. inermis*, Tullb., are specifically identical, a view in which we entirely concur. In 1847 Nicolet, as noted by Lubbock, evidently applied the name *fimetaria* to the variety with eight elevations in the post-antennal organ; but it is clear Lubbock himself did not restrict the name to that form, for although his words, "post-antennal organ consisting of sixteen elevations in two

oblong groups," are rather ambiguous, his figure ("Monograph," plate lvi. fig. 26) distinctly shows fourteen elements. In 1869, a year after Lubbock's notes in *Transactions of the Linnean Society*, Tullberg named the form with fourteen prominences, which appears to be the usual one both in Europe and America, *L. inermis.* Most of our specimens have fourteen to sixteen prominences in the post-antennal organ; a few, however, have only ten to twelve, and one has but nine, as shown in our figure. Japanese examples examined by Folsom had all eight or nine elements.

The species is widely distributed abroad—Scandinavia and Finland to Bohemia and Italy; also North America, Japan, and Sumatra.

Local data.—Common under flower-pots in greenhouses, etc., in several gardens in the Morningside district of Edinburgh, Dec. 1898 and Jan. 1899; Moredun limestone quarry, April, one.

Genus **Anurida,** Laboulbène.

Anurida maritima (Guer.), Laboulb.

Lipura maritima, Lubbock's "Monograph."

This interesting species is at times common on the surface of rock pools on the coast of East Lothian. Lubbock received it from Ireland (where it occurs on the east, south, and west coasts), and believed he had seen it at St Andrews. Only recorded from the shores of Scandinavia, the British Isles, Heligoland, France, and North America.

Local data.—Common in rock pools at Aberlady in Aug. 1896, and at North Berwick in Aug. 1897; St Andrews, Fife (Lubbock).

Anurida granaria (Nic.).

Anoura granaria, Lubbock's "Monograph."

We have not found this distinct species often, but it is evidently not uncommon locally. It inhabits the same kinds of places as the *Lipuræ,* to which it bears a strong superficial resemblance. Lubbock records it from England, and its range throughout Europe is extensive—Scandinavia and Finland to the Tyrol; Ireland and France to Bohemia. It has also been found in Franz Josef Land and Siberia.

Local data.—Craigentinny Meadows, near Edinburgh, fairly common under logs, Feb. 1899; Aberdour (Fife), Feb., one specimen; Morningside, under flower-pots in greenhouses, March and April, a good many.

Genus **Anura,** Gervais (= **Neanura,** MacG.).

Anura muscorum (Templ.).

Generally distributed, and common throughout the area under loose bark, fallen boughs, moss, etc. Occurs all through the year. The species is known to range from Siberia, Finland and Norway, to Ireland, Italy and Austria.

Local data.—Luffness Woods, Sept. 1896; Rosslyn Glen, Penicuik, Colinton Dell, Dreghorn, Braid Hermitage, Ravelrig, Corstorphine Hill, and Abercorn, common, Oct.; Ratho and near North Queensferry, Nov.; Vogrie, Feb. 1897; Cullalo and Dollar, April; Aberfoyle, Sept.; Balerno, Oct.; Carribber Glen, Feb. 1898; Dalhousie, Hallyards near Kirkliston, March; Bavelaw Bog, March 1899, two in wet *Sphagnum;* near Midcalder, May, a few; etc.

Order THYSANURA.

Family **CAMPODEIDÆ.**

Genus **Campodea,** Westwood.

Campodea staphylinus, Westw.

This curious creature, at first glance suggestive of a small Myriapod rather than of a true Thysanuran, is common among loose, damp earth, leaf-mould, under stones, etc., and seems to be very generally distributed over the district. It probably occurs throughout Europe.

Local data.—Fairmilehead and Mortonhall, July 1896; Gosford, Aug.; Gullane, Sept.; Rosslyn, Penicuik, Abercorn, etc., Oct.; Braid Hills, March 1897; Aberdour and Dollar, April; North Berwick, Aug.; Longniddry, Sept.; Bridge of Allan, Feb. 1898; Carribber Glen, Dalhousie, and Burntisland, March; Arniston, May; Linlithgow, Aug.; etc.

Family **LEPISMIDÆ.**

Genus **Lepisma,** Linnæus.

Lepisma saccharina, Linn.

This well-known insect—popularly called "sugar-fish" or "silver-fish"—is still to be met with in many parts of the

district in kitchens, bakehouses, and other places where a certain amount of artificial heat is rarely wholly wanting; but in our experience it is less frequent in dwelling-houses now than formerly. Abroad it occurs over the greater part of Europe and in North Africa, etc.

Local data.—In a bakehouse, Newington, Edinburgh, 1881; in cottage, Grange, Edinburgh, 1896; Morningside Dairy, under sacks in engine-house, abundant, Nov. 1896; kitchen in Buckingham Terrace, Edinburgh, April 1898 (Dr Sprague); in dwelling-house, Penicuik, many years ago; Aberlady, Sept. 1886; St Andrews, Aug. 1895 (from Mr J. W. Young); etc.

[**Thermobia domestica** (Pack.).

Thermobia furnorum (Rov.).

In the beginning of 1877 Mr James Simpson found a Lepismid in large numbers in the engine-room of a biscuit factory, then in Earl Grey Street, Edinburgh, and sent specimens to the late Dr Buchanan-White, who, being unable to name them, published a diagnosis (as "*Lepisma* —— ?") in the February 1877 number of the *Scottish Naturalist* (vol. iv. p. 46). In April a fuller note by Mr Simpson was communicated to the Royal Physical Society, and afterwards printed in the *Proceedings* (Vol. IV. p. 187). As Mr R. M'Lachlan has pointed out in the *Entomologist's Monthly Magazine* for 1895 (p. 75), there is no doubt that the insects in question belonged to the above-named foreign species, whose discovery about ovens in bakehouses in London and Cambridge formed the subject of several interesting notes in the 1894 volume of the magazine just mentioned. Mr Simpson tells us he does not now possess any specimens of the Edinburgh Lepismid, a microscopic slide of scales, which he has kindly sent us, being the only relic he has; and we have been unable to discover whether the creature still exists in Edinburgh.

Thermobia domestica may be known from *Lepisma saccharina* by its larger size and variegated appearance, as well as by the structural difference in having 6-segmented instead of 5-segmented maxillary palpi. It has been recorded from the United States, Italy, and Holland; and if it be identical with the *Lepisma parisiensis* of Nicolet, its occurrence in

France is of old standing. To this country it no doubt found its way in foreign goods.]

Family **MACHILIDÆ.**

Genus **Machilis,** Latreille.

Machilis polypoda (Linn.).

We have found small colonies of this Bristle-tail in several localities, among heaps of stones, etc., in hilly places and in old quarries; but, except in a few spots, it can scarcely be called a common insect here. It appears to have a preference for dry sunny situations. It is common in Ireland; but rare in the south of England, according to Lubbock. Abroad it seems to be widely distributed over Europe, and its range extends to North Africa.

Local data.—Blackford Hill, Edinburgh, several, May 1895; Arthur's Seat, common, and in limestone quarry, Charlestown (Fife), several, Feb. 1896; Aberfoyle, a few, April 1896; Bridge of Allan, one under moss on wall, Feb. 1898.

Machilis maritima (Leach).

This fine species is abundant under stones at or near high-water mark on the coasts of East Lothian and Fife, and on the islands of the Firth of Forth. It occurs commonly on the rocky shores of England, Ireland, France, and Norway; and it has also been recorded from Orkney and Shetland, and from the Canary Isles.

Local data.—Beach near North Berwick, common, Dec. 1895, etc.; shore west of Aberlady, abundant, July and Sept. 1896; Aberdour, March 1896, common; Isle of May, a good many, Aug. 1897; etc.

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Explanation of Plates V., VI., VII., and VIII.

The figures have all been drawn direct from specimens collected in the Edinburgh district. In Plates VI., VII., VIII., feet and mucrones are, as a rule, magnified 180, and antennæ 60 diameters. The structural figures (nearly all by G. H. C.) and those of the entire insects (all by W. E.) were drawn from different specimens.

Plate V.

Fig. 1. *Sminthurus hortensis*, Fitch; × 37. From a Morningside specimen (1896); natural length 1·15 mm. (lettered n.s. = natural size).

Fig. 2. *Sminthurus violaceus*, Reut.; × 50. From an Aberlady specimen; length ·75 mm.

Fig. 3. *Sminthurus malmgrenii*, Tullb., var. *elegantulus*, Reut.; × 75. Bavelaw Moss; length ·5 mm.

Fig. 4. *Isotoma grisescens*, Schäff.; × 31. Hallyards, near Ratho; length 2 mm.

Fig. 5. *Isotoma sensibilis*, Tullb.; × 34. Dalhousie; length 1·75 mm. 2nd abdominal segment made rather long in fig.

Fig. 6. *Isotoma schötti*, Dalla Torre; × 26. Beach west of Portobello; length 2 mm.

Fig. 7. *Achorutes longispinus*, Tullb., var. *scoticus*, nov.; × 31. Bavelaw Moss; length 1·5 mm.

Fig. 8. *Achorutes rufescens* (Nic.); × 48. Longniddry; length 1 mm.

Plate VI.

Fig. 1. *Sminthurus novemlineatus*, Tullb., var. *insignis*, Reut. Antenna.

Fig. 2. ,, ,, ,, ,, ,, Foot (1st pair).

Fig. 3. *Sminthurus novemlineatus*, Tullb., var. *insignis*, Reut. Dens and mucro from above; × 60.

Fig. 4. *Sminthurus novemlineatus*, Tullb., var. *insignis*, Reut. Mucro from side.

Fig. 5. *Sminthurus bilineatus*, Bourl. Antenna.

Fig. 6. ,, ,, ,, Foot (3rd pair).

Fig. 7. ,, ,, ,, Dens and mucro from above; × 90.

Fig. 8. ,, ,, ,, Mucro from side.

Fig. 9. *Sminthurus hortensis*, Fitch. Antenna; × 150.

Fig. 10. ,, ,, ,, Foot (1st pair); × 200.

Fig. 11. ,, ,, ,, Foot (3rd pair); × 200.

Fig. 12. ,, ,, ,, Mucro; × 200.

Fig. 13. *Sminthurus luteus*, Lubb. Antenna.

Fig. 14. ,, ,, ,, Foot (all three pairs are closely alike).

Fig. 15. ,, ,, ,, Mucro.

Fig. 16. *Sminthurus quadrilineatus*, Tullb. Antenna.

Fig. 17. ,, ,, ,, Foot (1st pair).

Fig. 18. ,, ,, ,, Foot (3rd pair).

Fig. 19. *Sminthurus quadrilineatus*, Tullb. Mucro.
Fig. 20. *Sminthurus igniceps*, Reut.; × 30. Natural length ·9 mm.
Fig. 21. ,, ,, ,, Antenna; × 90.
Fig. 22. ,, ,, ,, Foot (3rd pair).
Fig. 23. ,, ,, ,, Mucro.

Plate VII.

Fig. 1. *Sminthurus violaceus*, Reut. Antenna; × 100.
Fig. 2. ,, ,, ,, Foot (1st pair); × 200.
Fig. 3. ,, ,, ,, Foot (3rd pair); × 200.
Fig. 4. ,, ,, ,, Extremity of dens with mucro; × 200.
Fig. 5. *Sminthurus malmgrenii*, Tullb., var. *elegantulus*, Reut. Antenna.
Fig. 6. ,, ,, ,, ,, ,, Foot (1st pair).
Fig. 7. ,, ,, ,, ,, ,, Foot (3rd pair).
Fig. 8. ,, ,, ,, ,, ,, Mucro.
Fig. 9. *Sminthurus cæcus*, Tullb., var. *attenuatus*, nov. Head and antenna; × 60.
Fig. 10. ,, ,, ,, ,, Foot (1st pair); × 180.
Fig. 11. ,, ,, ,, ,, Foot (2nd pair).
Fig. 12. ,, ,, ,, ,, Foot (3rd pair).
Fig. 13. ,, ,, ,, ,, Mucro; × 180.
Fig. 14. *Papirius ornatus*, Lubb. Mucro.
Fig. 15. ,, ,, ,, Foot (3rd pair).
Fig. 16. *Tomocerus niger* (Bourl.). Foot.
Fig. 17. *Isotoma viridis*, Bourl. Mucro.
Fig. 18. *Isotoma palustris* (Müll.), var. *maculata*, Schäff.; × 15. Natural length 2·5 mm.
Fig. 19. *Isotoma palustris* (Müll.), var. *maculata*, Schäff. Mucro.
Fig. 20. *Isotoma maritima*, Tullb. Head; × 60.
Fig. 21. ,, ,, ,, Foot.
Fig. 22. ,, ,, ,, Mucro.
Fig. 23. *Isotoma grisescens*, Schäff. Left ocelli and post-antennal organ; × 180.
Fig. 24. ,, ,, ,, Foot (3rd pair).
Fig. 25. ,, ,, ,, Mucro.
Fig. 26. *Isotoma sensibilis*, Tullb. Foot (3rd pair).
Fig. 27. ,, ,, ,, Mucro.

Plate VIII.

Fig. 1. *Isotoma cinerea* (Nic.). Foot (1st pair).
Fig. 2. ,, ,, ,, Mucro.
Fig. 3. *Isotoma fimetaria* (L.), Tullb. Foot.
Fig. 4. ,, ,, ,, Mucro.
Fig. 5. *Isotoma spitzbergenensis*, Lubb.; × 29. Musselburgh; length 1·75–2 mm.
Fig. 6. *Isotoma spitzbergenensis*, Lubb. Head showing ocelli and post-antennal organ; × 60.

Fig. 7. *Isotoma spitzbergenensis*, Lubb. Foot.
Fig. 8. " " " Mucro.
Fig. 9. *Isotoma schötti*, D. T. Foot.
Fig. 10. " " " Mucro.
Fig. 11. *Xenylla humicola* (O. Fabr.); × 29. Aberdour; length 2 mm.
Fig. 12. " " " Foot.
Fig. 13. " " " Dens and mucro.
Fig. 14. " " " Extremity of abdomen, showing anal papillæ and spine.
Fig. 15. *Achorutes longispinus*, Tullb., var. *scoticus*, nov. (side view); × 31. Bavelaw; length 1·5 mm.
Fig. 16. *Achorutes longispinus*, Tullb., var. *scoticus*, nov. Extremity of abdomen, showing right spine, etc.; × 120.
Fig. 17. *Achorutes longispinus*, Tullb., var. *scoticus*, nov. Foot.
Fig. 18. " " " " " Mucro.
Fig. 19. *Achorutes rufescens* (Nic.). Extremity of abdomen; × 120.
Fig. 20. " " " Foot.
Fig. 21. " " " Dens and mucro from above; × 90.
Fig. 22. " " " Mucro from side.
Fig. 23. *Triæna mirabilis*, Tullb.; × 44. Pentlands; length 1 mm.
Fig. 24. *Lipura fimetaria* (Nic.). Right post-antennal organ and ocelliform punctures, as seen in one of our specimens; × 180.

XIX. *Contributions to the Natural History of the Polar Bear* (Ursus maritimus, *Linn.*). By REGINALD KOETTLITZ, M.R.C.S.Eng., F.R.C.P. Communicated by WILLIAM S. BRUCE, F.R.S.G.S.

(Read 16th November 1898.)

This paper is supplementary to Messrs Bruce and Eagle Clarke's communication on the "Mammals and Birds of Franz Josef Land,"[1] and is based on observations made on over one hundred and twenty bears seen by me during my sojourn in Franz Josef Land with the Jackson-Harmsworth Polar Expedition during the years 1894 to 1897. Of these sixty-nine were shot, forty-seven being males, twenty-two females. Cubs were generally captured alive. The following table shows the number seen and taken alive each month and their sex:—

[1] *Vide* Vol. XIV. pp. 78-112.

AUGUST 1894 TO AUGUST 1897.

	Males.	Females.	Sex not ascertained.	
January, . .	7	1	3	besides cubs.
February, . .	6	3	6	including 1 cub.
March, . .	7	4	7	including 2 cubs.
April, . .	5	1	13	
May, . .	2	2	1	
June, . .	5	2	3	
July, . .	1	0	4	
August, . .	3	2	3	
September, .	1	4	3	
October, . .	3	1	2	
November, .	6	1	5	
December, .	1	1	3	
	47	22	53 = 122 Total.	

Thus there were more than twice as many males as females shot. To my mind this suggests, not that there are really fewer females, but that the female is more wary, and remains more about one locality near land. This is especially so when she has cubs. Adult males are, as a rule, larger than adult females, though they vary much in size, being 7 feet 4 inches to 8 feet 1½ inch from the tip of their nose to the tip of their 6-inch tail. Females average 6 feet 6 inches. The average weight of a male bear is 820 lbs. Only one female was weighed; she was 303 lbs. This was after parturition and "hibernation"; she also seemed septicæmic.

With cow-like curiosity, rather than fierceness, the polar bear walks around in a desultory manner, examining and sniffing at everything, and for this same reason will approach man, only occasionally attacking,—witness, for instance, the attack upon Lieutenant Johansen (Nansen's companion), also upon Dr (now Professor) Ralph Copeland and Börgen of the Second German Expedition. When wounded or cornered, they have been known to turn and attack like a rat. They are easily scared by dogs or by a slight wound, such, as I have known, from a revolver, in which case they turn tail, almost invariably turning in their old tracks. They often defœcate when running away, especially if

wounded, micturate as they walk, also squat for the purpose like a pup, and then scratch like a dog with all four feet, scattering the snow behind them. A mother will, however, defend her cubs· with much fierceness if she cannot escape with them. Cubs which we captured showed persistent savageness and untameableness, being ever ready to bite and claw. When attacked the bear hisses, and when wounded loudly grunts or roars, but on nearly all other occasions the bear is a silent beast. On one occasion a bear took the remains of a walrus we had killed, and although he had gorged himself, refused to allow some ivory gulls to share his feast, always running at them and driving them away with hisses. On another occasion a she-bear seemed to roar encouragement to her cub when she saw it in imminent danger. They claw wood and other objects like cats do.

The only food I ever found in a bear's stomach was seal, though it is said to eat fish, white whales, and porpoises. I have examined perhaps as many bear stomachs as anybody, and the only animal food ever found in them was seal. When a bear catches a seal, he often eats the whole at one meal, bones, skin, hair, claws, teeth, everything. Young seals seem to be principally the food obtained, probably because more easily caught than old seals, for I have always found their ununited articular or immature bones, viz.: epiphyseal ends, and with detached shafts of bones and milk teeth in stomachs examined. The following is a list of stomach and intestinal contents that I have found:—

Seal remains were found in . . .	13
Grass, seaweed, etc., ...	6
Grass and seal remains, ...	2
Paper, ...	3
Manilla rope yarn, ...	1
Hard lump of woven texture, . . .	1
Horse dung and Macintosh sheeting, . .	1
Canvas, ...	1
Basaltic pebbles and chyme-like fluid, . .	1
Bear blubber (stolen from a cask near house), .	1

Nothing in others examined.

They do not eat grass because they are hungry, for I have found seal and grass together in their stomachs and intestines, and observed on one occasion that a bear directly after a meal of seal, went three miles for grass, of which it ate a quantity. It appears as though a bear feels a necessity for some vegetable food; possibly health has something to do with it.

Since seal is their chief food, it is natural that they should be numerous in the vicinity of seal-holes. This often accounts for them being met high up sounds and fiords, as far as eighteen or twenty miles from the nearest open water. They confine their perambulations for the most part to the floe-ice—whether it be fixed land-floe, or moving pack, or even small pieces of drift ice, is immaterial to them. They often take their passage from one place to another upon this moving ice, but they are occasionally to be found on the land, even apparently being aware of short cuts across a comparatively narrow piece of ice-covered land three miles wide, for their tracks have been noted as crossing such a stretch of low land from one to two hundred feet above the sea. Their tracks have also been seen ascending high land, as though they went up for the purpose of a look-out, such as they frequently do by ascending an iceberg. They pick the best path through hummocky ice, and many travellers have found it wise to follow their tracks.

I have ample evidence to show that the sight of the bear cannot be very sharp, besides the anatomical reason that the eye is small, is generally of a grey, dead fish's-eyelike colour, and the optic nerve not large—less in size, in fact, than the human. Similarly, hearing I judge not to be acute. In marked contrast, however, is his keenness of scent: by scent he guides himself to his prey, and the bears which visited our station invariably came up from leeward. On one occasion I saw a very good example of this. I was watching a she-bear with a cub; she was slowly moving along the edge of the land-floe about a mile and a half away, and at last arrived in a direct line to leeward of our station, whereupon she suddenly became alert, sniffed in the air to windward, and came up at a canter. When the wind blew

on shore we might expect bears, for they came in on the outer pack, when it impinged upon the land-floe. In stalking, they are most circumspect and deliberate, looking quite unconcerned and unconscious of anything they wish to investigate. Thus a young cub we had would stalk and seize some pups, whose yells alone would proclaim the fact. To see their prey more clearly, they will raise themselves on their hind legs, crane their necks, and even jump up when in this posture. In my opinion, the polar bear never hugs; it strikes with its fore paws and claws, and may attempt to seize with the mouth. Defending itself from the attack of dogs, it faces them, and will back up to a berg or hummock as a vantage point.

Once I saw a bear stalking a seal in a small pool among the pack-ice. For ten minutes the bear squatted on his belly watching, intently expectant, and ready to strike, but when he saw the game was gone, he slowly withdrew. Before this event he was approaching our ship, but now he had forgotten or lost all interest in her. With their curiosity is combined destructiveness; they would rip up tins in our depôts and tear down flags. Sometimes they will abstain from molesting. I have known bears come quite close to our camp, investigate ponies, sleeping dogs, etc., and go away again. On the other hand, I have known them kill a sleeping dog wantonly, leaving it uneaten. Bears will glissade down steep slopes. Bears do not necessarily get thin in the winter. I have notes of many being fat and in excellent condition. It would appear that the less skilful hunters, such as old or young bears, only are the thin ones: they can undoubtedly continue a considerable time without food, and not suffer much.

The coat during summer is more ragged and yellow than during winter; for then they are casting their coat, and the hair is old, has lost its gloss, is dying in fact; and some parts not infrequently are almost bare — the belly, for instance. It matches well with the frequent yellow pieces of ice in the summer pack. The perfect winter coat is creamy white, and is also difficult to see among its more wintry surroundings.

The bear already referred to above, which had taken possession of half the skin and the head of a walrus we had killed some days before, had stripped the skin of its blubber, leaving the meat, and was so gorged that his belly reached within six or nine inches of the ground when he stood. He could not possibly eat any more, yet he guarded what remained from the ivory gulls and ourselves with determination. He would make rushes, and hiss at the ivory gulls, driving them off, and would then try to rest upon his belly at full length, or with his hind legs under him, and his fore legs folded together like a cat; then he would yawn and roll over on his back, and yawn again. He hissed at us if we approached him, and when we made as if to take the other half of the skin, he came and carried it away in his mouth, jumping across 5-foot cracks, and slinging it over after him with the greatest ease, as if it were the weight of a wet towel, although it would have taken four or five of us to drag it over the ice. He showed no fear, but only attacked us or the gulls when we threatened to steal his food. Eventually we shot him as he ran threateningly at us, when we approached him and his food. He was a big bear, measuring 8 feet 1¼ inch from his nose to the tip of his tail.

Males and females are never seen in company; both lead a lonely, wandering life—their home is the ice, and their wanderings must cover a large area. Probably Franz Josef Land bears are as much at home in the Kara as the Barent's Sea, in Novaya Zemlya, and Spitzbergen, or Wiche Islands, as in Franz Josef Land. The exception when they are not alone, being a mother with her cub, and in the rutting season.

If the rutting season occurs at particular times, I am inclined to think it is at least twice a year. One of these periods is probably early in March, when we saw a male and female together; the other at the end of August and beginning of September. On the 6th of December a pregnant young female was shot, the two fœtus measuring 4¼ inches in length, and being between two to three months old. On the 25th of August and 2nd of September she-bears were

shot, in which I found in one ovary of each a large false corpus luteum, which I judged was about two weeks old; they were $\frac{1}{2}$ to $\frac{3}{4}$ inch in diameter. This suggests that another rutting period occurs about the month of August: neither of these bears were gestating. Very young cubs were only seen in February and March, older cubs were to be seen at the end of winter. In one case we obtained a cub under one week old in a hibernating hole on 3rd February. From this fact, and from seeing the two together early in March, it would suggest that the gestation period was between ten and eleven months. Cubs seem to continue with, and be suckled by, their mother for nearly two years.

The very young cub referred to had its eyes open. The weight of twin cubs, shot on 15th January, was 234 lbs., and were judged about a year old; milk was in their mother's mammæ, and freshly killed seal in their stomachs. Twins are perhaps most frequent.

I do not consider that the Polar Bear hibernates. Out of one hundred and nineteen adults, and about five cubs, forty-three, or more than one-third of the whole, were met during the Arctic night of four months. Had it been light, more would have been seen, hence the statement that "in the most northerly wintering places of ships, the bears almost completely disappear,"[1] must be refuted. Again, it is said[2] the thymus gland exists throughout life, and enlarges every hibernation in hibernating animals. But I have never found the thymus gland in an adult bear, not even when actually in a so-called hibernating hole. Payer,[3] quoting Richardson, says: "it is only pregnant females who hibernate in a snow-hole, while the males roam over the Arctic Seas in search of places free from ice." My list shows that during the winter months almost the same number of females were seen as during the summer months. That pregnant females do not necessarily hibernate is supported by the fact that we shot one, with twin fœtus two to three months old, on 6th December, after forty-seven days of the Arctic night,

[1] "Royal Natural History" (Lydekker), vol. ii. p. 5.
[2] Kirkes, "Handbook of Physiology," 1892, p. 521.
[3] "New Lands within the Arctic Circle," vol. ii. p. 107.

wandering about on the ice: she had been eating seal. That they dig holes occasionally, and become drifted over and buried for a time is undoubted, for we came across five such cases. But that they actually hibernate is open to question. A non-pregnant female was found buried on 14th October, probably to shelter herself from a strong gale which was blowing. The hole had just been made. Seven days previously we found an unfinished hole; the bear which had made it had been shot, and was a male. On 3rd February a hole was discovered, a female bear being inside, with a newly-born cub. The cub was, perhaps, a week old; lochia was coming away from the mother; the uterus showed recent birth, and the placenta had evidently been eaten. Two other untenanted holes were found, one apparently being that of a small bear. Three of these were made in snow-drifts, in hollows on the land, and two upon the floe in the fiords. A bear, therefore, does not necessarily choose land upon which to make it.

I measured these holes. The one of 14th October was 6 feet long and 3 feet deep; the roof was 1 foot thick, and there was a ventilating hole at the hinder quarters of the bear lay. There was a heap beside it that had been thrown out by the bear. The roof had evidently been formed by drifting snow. There were claw marks all round the sides of the hole. The bear was shot while breaking through the roof, having been disturbed by dogs. The one of 3rd February was a long hole, being 15 feet 10 inches long, and divided by a waist into two compartments; the deeper and larger cavity was evidently the one recently occupied, and was 3 feet deep, 5½ feet wide, and 7 feet long; its floor was continued, and slightly rising into the second compartment; the waist was 18 inches high and 3 feet wide; the second compartment widened again to 6 feet, was 2 feet high, and ended with a long spiral communication with the outer air, 6 inches in diameter. The rise in the floor of the second named compartment was probably due to compressed dug out snow from the larger one. This bear was shot while breaking through the roof of the larger compartment, in which she was evidently living, and her cub

taken alive. About 2 feet of snow had been drifted over the hole.

This newly-born cub was reared by us in the house. Its dimensions were,—

Length.—26 inches to tip of tail.

Girth.—Chest, 16½ inches; abdomen, 19¼ inches.

Head.—Length, 7 inches; circumference, 13 inches; breadth between ears, 4½ inches; length of nose, 1¼ inch; width between eyes, 2 inches.

Foreleg.—10¼ inches long.

Hind Foot.—4½ inches long.

Weight.—17 lbs.

Dentition.—Upper and lower canines well through gum; lateral upper incisors through gum; middle, upper, and all lower incisors still uncut and below the gum; six days afterwards four lateral incisors of upper jaw, two lateral lower incisors; first molars of both jaws were through the gums besides the canines.

The cubs shot on 15th January weighed 234 lbs., and were probably one year old or more. Their dentition was,—Temporary lateral incisors just on point of being shed, but not loose; tips of permanent teeth showing alongside; milk canines quite small, but not loose; tips of permanent canines showing through gums.

The dentition of the adult bear is I. $\frac{3}{3}$, C. $\frac{1}{1}$, P.M. $\frac{3}{2}$ or $\frac{4}{2}$, M. $\frac{2}{3}$.

Most of the premolars are very small; sometimes the third upper premolar may only occur on one side. The bears in which this extra tooth is found are not necessarily the larger specimens. Those bears also that did not show them had not a trace of them under the gum. The teeth in old bears are much worn and blunt.

The Polar Bear has an extraordinary tenacity of life. It seems to suffer very little shock, even after being desperately wounded. The young cub shows similar tenacity of life. We kept three in the house in a warm atmosphere, with very little exercise, fed on sweet condensed milk, bear, walrus, and other meat (cooked or raw), biscuit, in fact anything, and yet they throve. The youngest was once nearly dead with

diarrhœa and in severe pain. A good dose of castor oil and chlorodyne put it all right again.

The muscles of the bear are enormously developed. Those of the neck, shoulder, and arms are magnificent. Consequently ridges for muscular attachment are very prominent. With regard to the interparietal ridge, I am, indeed, inclined to think that there are two varieties of bear, one in which this ridge does not develop markedly, and another in which it does, which latter has also a smaller brain, and is a more scary animal. The rump is higher than the shoulders. This tends to increase the ungainly shape and awkward-looking movements so characteristic of the bear.

Wounds and scars are frequent, especially on the males. The more recent I noticed to be more common in spring, and are probably caused through fighting over females at rutting times. The wounds are always septic. Small wounds in the feet are common; in one female such wounds caused inflammatory synovitis in the sheaths of the flexor tendons in the fore leg, with consequent lameness in walking.

Fractures of bones are not uncommon. On one occasion I found four fractured and partially united ribs, with a large amount of callus. An external wound of large size had evidently been associated with it, but it had not been a compound fracture. I observed fracture of carpus, tarsus, zygoma, and possibly lower jaw. Carious teeth also occur. In one case the lower left canine was almost destroyed, and the bear had suffered considerable pain, for extensive periostitis had been induced, and the jaw bone, with the alveolus, was enormously swollen all round it. The *os penis* was found, more than once, fractured and reunited at an angle.

The testes appear to descend late. The female has four mammæ. The anterior pair are placed on the thorax, in the same position as in man; the posterior pair 6 inches behind. The mamillæ appear to have a central duct.

The bowel is enormously long, being 180 feet; there is no apparent colon, but the rectum is continuous with the small intestine. Tæniæ or other Entozoa were never discovered by me infesting it. Many portions of seal remains pass undigested through the intestines, such as fragments of

bone, teeth, skin, hair, etc., having been found in the lower gut.

The adipose tissue accumulates mostly in the hind quarters, in the omentum, and mesentery; it is frequently 3 inches thick over the buttocks, back, and thighs. When a bear is very thin, the little adipose tissue found is very granular, and appears to have very little oil in it; it is then of a much brighter yellow than usual.

The brain is a small one, but varies extraordinarily in weight. Old bears' brains frequently weigh 16 ounces, whereas a cub may have one 17½ ounces. The following are weights taken by me:—

Large males, 18½, 19½, 18½, 20, 16, 17 ounces each.

Average males, 16, 18, 15½, 16, 19¾, 17½, 16½, 16¾, 18½, 16 ounces each.

Small males, 15½, 13¼ ounces each.

Females, 18, 16, 16, 19¼ ounces each.

Cubs, 17, 17¼ ounces each.

The average is therefore about 17 ounces.

Cysts are very common on the skin of the head and neck especially, though they are occasionally also to be found on the rest of the body. These cysts range in size from a split-pea to that of a filbert nut, and on some bears are very numerous. They are probably sebaceous, but they nearly always contain, besides cheesy material, masses of coiled-up hair.

One case of fibrous tumour was observed. It was inclined to be pendulous, and was attached to the lower gum at the junction between it and the lip, at about the middle line, and caused the lower lip to protrude a good deal; it was of the size of a walnut.

A case of exostosis came also under observation, situated upon the symphysis of the lower jaw. This was about an inch and a half in diameter, and protruded an inch. It was composed of compact bone.

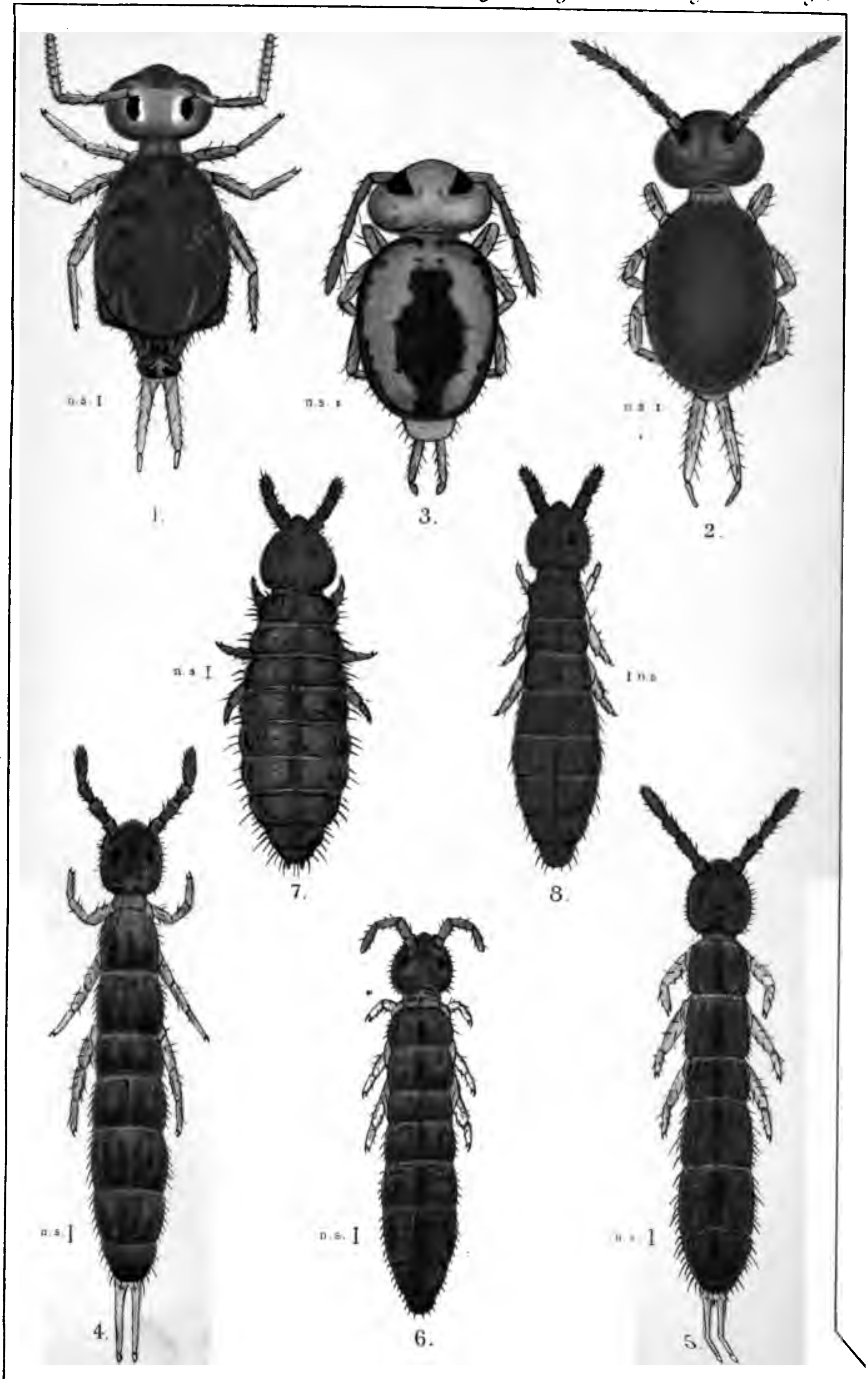
I also came across a salivary calculus in the parotid. It was irregular in shape, and the size of a large bean.

Arthritis deformans, or osteo-arthritis, is not infrequent among bears. I found several examples of this condition. In one case—the worst I saw—the bones of all the four feet

were considerably enlarged, especially in the neighbourhood of the joints; large outgrowths thoroughly deformed all the bones; even the sesamoid bones were affected. The bear which was so affected was not old, was a large, well-nourished one; but it walked, I noticed, a little lame before it was shot. It would thus appear that the wet, cold, and exposure cause this condition in the bear, the same as in man; the bear, being especially exposed to these, is not exempt from the morbid consequences.

In the course of the three years that we occupied the station at Cape Flora, the continual hunting of these animals appears to have made a sensible difference in their numbers. During the first year, nearly sixty were shot; some escaped but wounded, and others untouched. During the second year, twenty-four were shot; one or two got away badly wounded, and several others were seen. But during the third year only ten were shot, and about ten to fifteen more were seen. It thus seems as though the hunting them in one locality either sensibly diminishes their number in that part, or else that they learn to know it and avoid it.

There is one point about which doubt is often cast, and that is the peculiar effects which occur in man after eating the bear's liver. I was myself very sceptical upon that point, but on several occasions one or two of us ate of the liver once or twice, never thinking of any consequences, but in about four or five hours a gradually increasing frontal headache, of a cumulative, congestive type, came on, which nothing would ease. Lying down makes it worse instead of better; one cannot sleep for it; it gets steadily worse for about six or eight hours; occasionally nausea and vomiting comes on, especially if much has been eaten; and altogether one is in a most miserable condition. After about this time has passed, the symptoms gradually decrease in severity, until after twenty-four hours have intervened, one is relieved sufficiently to be able to sleep, and upon awakening the headache is gone. Eating bear's kidney seems also occasionally to cause the same symptoms, but in a much less degree. Ivory gulls and other birds avoid the liver and kidneys, rarely eating them, and then only sparingly.



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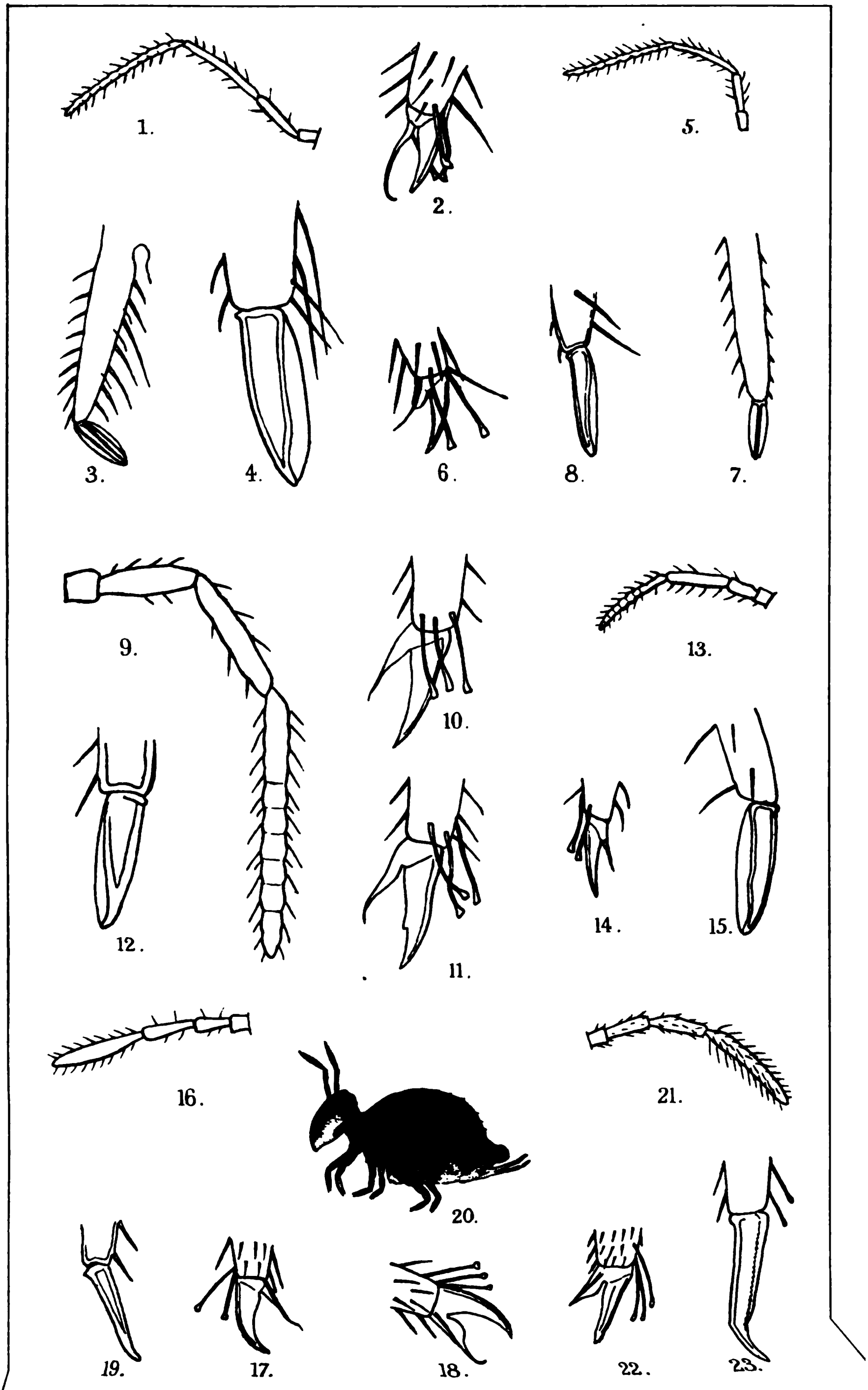

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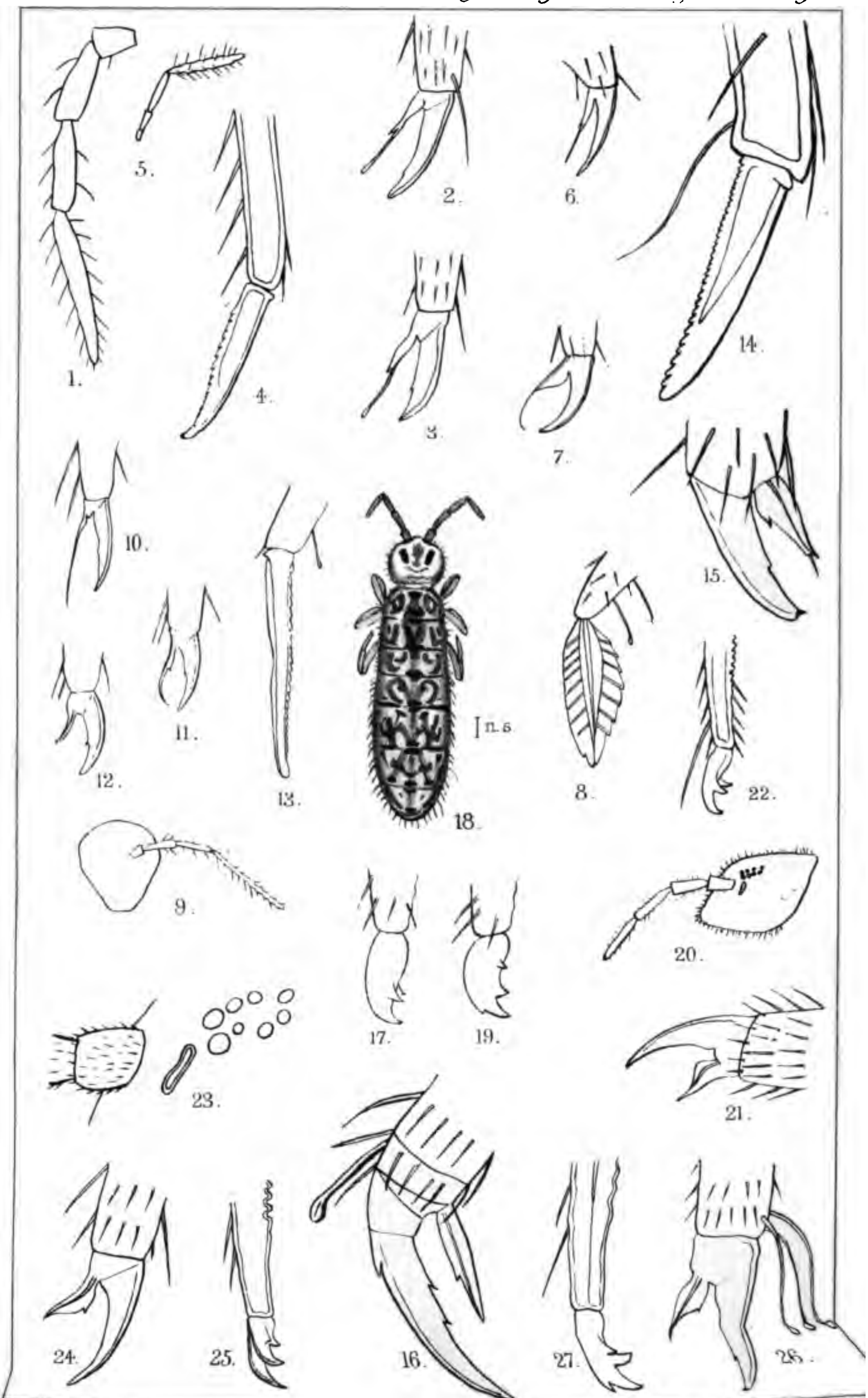

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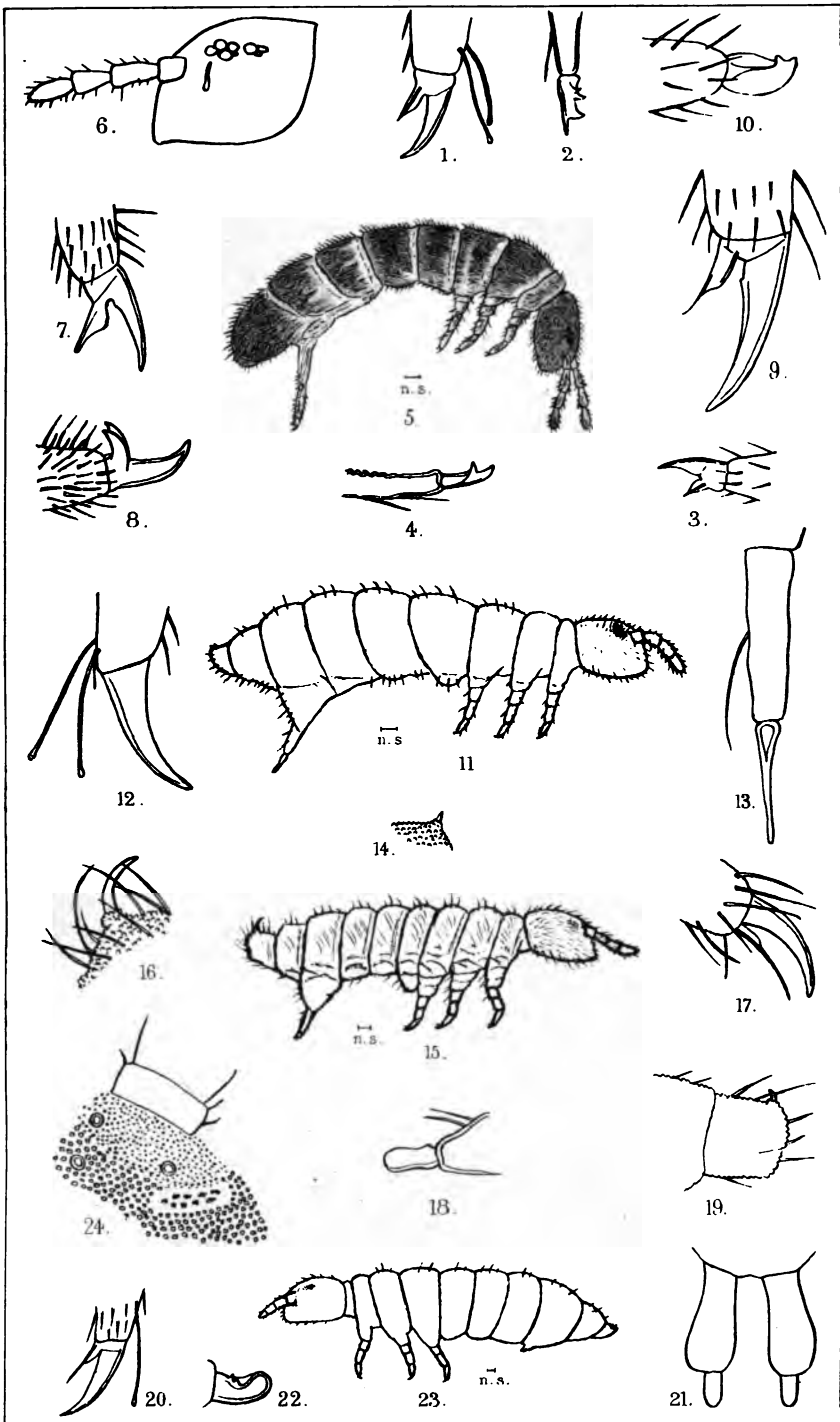

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PROCEEDINGS

OF THE

ROYAL PHYSICAL SOCIETY.

SESSION CXXIX.

Wednesday, 15th November 1899.—BENJ. N. PEACH, F.R.S., F.G.S., President, in the Chair.

Dr ROBERT MUNRO, M.A., Vice-President, delivered the following opening address, entitled "Stray Thoughts on the Theory of Organic Evolution, more especially as applied to Man":—

As senior Vice-President of this Society, the customary duty of delivering the opening address devolves upon me. In a Society whose fellows are chiefly engaged in special studies, ranging over the wide domain of natural science, this custom has many advantages, not the least among them being the opportunity it gives of ventilating, in a discursive manner, some of the more general and speculative opinions current in the scientific world. While fully recognising that, in the present advanced state of knowledge both in physics and biology, it is scarcely possible for any student to win laurels as an original investigator in either of these departments, without devoting the larger portion of his time and energies to some restricted groove of research, we must not forget that the attainment of this desirable object is greatly facilitated by keeping himself *au courant* with the more salient discoveries in the collateral sciences. On scanning the wide field before me with the view of selecting a subject suitable for the present occasion, many topics

cropped up before the mind's eye. Among these may be mentioned the favourite subject of stock-taking of recent work done in one or other of the departments of science in which you are engaged. But the limitation of my special knowledge in most of them precluded me from entertaining any project of this kind. A man who cannot swim should never go beyond his depth. I find it, therefore, more prudent to restrict myself to a mere academic performance, leaving to more competent men, such as our President and Secretary, the duty of garnering the fruits of your own labours as discoverers and investigators. In laying before you a few stray thoughts on the theory of Organic Evolution, more especially in its bearing on the human race, I claim your indulgence if in some instances I utilise facts which are known to me only through the researches of others.

That all the higher animals which form so conspicuous a portion of the organic world around us are genetically connected by descent from common ancestors, may now be accepted as a settled dogma in biology. The evidence, however, on which this important generalisation is founded, scarcely admits of experimental proof, because these ancestors are no longer in life, owing to the inexorable law which assigns to every individual organism, after a more or less limited period of existence, a return into the bosom of mother-earth. Indeed, of the vast majority, no traces are now to be found, and the only means we have of procuring any information of their former existence and characteristics is by a laborious investigation of casts or impressions of the bodies of some specimens which, by a combination of fortuitous circumstances, have become stereotyped in the crust of the globe. Such fossil remains, however, disclose little more than the outlines and fragmentary skeletons of these by-gone creatures, but yet, in the hands of skilled palæontologists, they have been made to throw a flood of light on the dogma now under consideration. To fully understand the doctrine of evolution, one has, therefore, not only to examine living fauna as regards the resemblances, differences, physical environments, and geographical distribution of the different species, but

also to trace their fossil predecessors throughout a long series of geological periods from the dawn of life on the globe down to the present day. When a common ancestor to two or more present-day species is disinterred, we have to carry our imagination back to the time when it was an individual member of a living species, similarly affiliated to pre-existing predecessors—for however distant the relationship of a fossil may be from its present representatives, whether it be regarded as a genus, family, or order, the day was when it flourished as a species. By continuing this line of investigation backwards in time, through the successive sedimentary strata which form the larger portion of the earth's crust, we gradually encounter less and less specialised forms, till ultimately the most divergent types meet in a common origin among unicellular organisms, analogous to those still prevalent on the borderland of the animal and vegetable kingdoms, such as the amœba, red-snow plant, yeast, etc.

Another important generalisation, which has been demonstrated by the dissection of animals, is that, however dissimilar living forms may appear, they are structurally but a congeries of unicellular organisms grouped together on a uniform plan, and working in the animal economy on the principle of the division of labour. Now, many of these lower organisms exhibit, though, of course, in a most rudimentary manner, nearly all the vital phenomena of the higher animals—voluntary motion, assimilation of food, growth and maintenance, reproduction, decay and death. The human body may thus be regarded as a combination of groups of *amœbæ*, so arranged as to subordinate their original individualism to the general welfare of the compound organism. In the course of long ages these cell units have become adapted in various ways for their special work by entering into the structure of the animal's tissues, or floating about as corpuscles in blood and secretions. Thus they build up cellular membrane, muscular fibre, medullary matter, brain cells, etc., by means of which all the animal functions are performed from simple molecular movements up to conscious cerebration. The theory, first propounded by Schwann about

the second quarter of this century, which represented the simple cell as the lowest form of life, was justly regarded as one of the greatest physiological discoveries of the age; and, although germs and protoplasm have since, to a certain extent, shared in this distinction, its function in the construction of the tissues still holds good. The *role* of cells in the elaboration of the bodies of animals and plants may be compared to that of bricks in a building, with this difference, however, that the former assume a great variety of forms—fusiform, caudate, stellate, squamous, ciliated, epithelial, etc., according to their position and function in the animal economy.

Continuing our general survey of the organic world, it may be further observed that between the unicellular organisms and the higher animals, there are numbers of intermediate forms more or less differentiated; and so gradual is their differentiation manifested, that the whole series may be compared to a chain having for one of its terminal links a unicellular organism and for the other man himself. But yet all these links are absolutely distinct and independent of each other, except on the lines of their genetic connection.

Another remarkable fact is, that the present-day species are never precisely similar to their fossil ancestors, from which it follows that some modification in the somatic structure of the former has taken place in the course of time; and it is significant that the extent of this modification corresponds, generally, with the time that has elapsed since the latter were in life. But this change has not been at a uniform rate in the different species, some having adhered so persistently to their peculiar structure and habits that they continued to flourish through several geological periods without having undergone any material modification. For example, the Lampshells, King-Crabs, Pearly Nautilus, and many others, have come down from Palæozoic times to the present day with comparatively little change during these millions of years. Indeed, so conservative were some of them that they preferred to die out rather than change their antiquated ways.

Such animals Professor Cleland very appropriately designates as "terminal forms of life." Among a number of examples of this class quoted by him, I shall only mention the Lampshells (*Brachiopoda*), a genus of which gives name to the Lingula Flags of the Cambrian period. "By what means," writes Professor Cleland, "the Lingula arose—with whatever ancestry—it had completed its development in those far-off days, long before the earliest trace of a vertebrate; and, after having completed its development, there it has remained, closing its valves through the long ages against all the changes in the outer world in that tremendous lapse of years which separates the deposit of the Lingula Flags from our own day. Surely to such a persistent genus as this we may fairly give the title of a terminal form" (*Journal of Anatomy and Physiology*, vol. viii. p. 350).

The same remarks apply to many of the Protozoa of the present day, especially unicellular organisms, some of which would be, probably, undistinguishable from their predecessors in all ages, had we the means of making a comparison between them. This idea is so far borne out by the organisms recently dredged up from the bed of the Atlantic, such as Foraminifera, Sponges, Corals, etc., many of which have been declared to be similar to analogous forms in chalk. On the other hand, at a much later period than the Cambrian, many genera and species had arisen, flourished for a time, and then vanished for ever. Such were the *Ichthyosaurus*, the *Plesiosaurus*, the Pterodactyle, and many other strange forms of swimming and flying reptiles, which became extinct towards the end of the Cretaceous period. The study of the life-history of these extinct animals is most fascinating to all lovers of the marvellous, and most instructive to the evolutionist.

Although many of the higher animals which had a wide range in the Tertiary period have also become extinct as species, yet their direct but greatly modified representatives are at the present time probably more numerous than at any former period. Apparently, the modifying influences have told upon them more quickly, so that transformations of considerable extent have been effected in a

shorter period. As a direct bearing on some of these points, the following remarks by Professor Huxley are of much interest:—

"If you divide the animal kingdom into orders, you will find that there are above one hundred and twenty. The number may vary on one side or the other, but this is a fair estimate. . . . Among the Mammalia and birds there are none extinct; but when we come to the reptiles, there is a most wonderful thing: out of the eight orders, or thereabouts, which you can make among reptiles, one-half are extinct. . . . If we turn to the Amphibia, there was one extinct order, the Labyrinthodonts.

"No order of fishes is known to be extinct.[1] Every fish that we find in the strata—to which I have been referring—can be identified and placed in one of the orders which exist at the present day. There is not known to be a single ordinal form of insect extinct. There are only two orders extinct among the Crustacea. There is not known to be an extinct order of these creatures, the parasitic and other worms; but there are two, not to say three, absolutely extinct orders of this class, Echinodermata; out of all the orders Cœlenterata and Protozoa only one, the Rugose Corals.

"So that, you see, out of somewhere about one hundred and twenty orders of animals, taking them altogether, you will not, at the outside estimate, find above ten or a dozen extinct. Summing up all the order of animals which have left remains behind them, you will not find above ten or a dozen which cannot be arranged with those of the present day; that is to say, that the difference does not amount to much more than 10 per cent.; and the proportion of extinct orders of plants is still smaller" ("Collected Essays," vol. ii. pp. 353–55).

There is another principle bearing on the variation of both plants and animals, which I cannot do better than introduce to you in the words of Professor Ray Lankester:—"Any new set of conditions occurring to an animal which

[1] As my friend Dr Traquair tells me, the classification of fishes has altered since Huxley wrote these words. The "Ganoidei" are no longer esteemed an order, and the Ostracodermi (*Cephalaspis*, *Pteraspis*, etc.), which used to be classed as Ganoids, form an absolutely extinct order, or rather sub-class.

render its food and safety very easily attained, seem to lead as a rule to Degeneration; just as an active healthy man sometimes degenerates when he becomes suddenly possessed of a fortune; or as Rome degenerated when possessed of the riches of the ancient world. The habit of parasitism clearly acts upon animal organisation in this way. Let the parasitic life once be secured, and away go legs, jaws, eyes, and ears: the active, highly-gifted crab, insect, or annelid may become a mere sac, absorbing nourishment and laying eggs" ("Degeneration," p. 33, 1880).

According to these views, degeneration has as firm a footing in the operations of nature as evolution, and although the palæontological evidence in support of it is necessarily obscure, the biological cannot be gainsaid. Among the animals which can be proved to be modified descendants of those of more elaborate structure, Professor Lankester instances parasites; some lizards, whose limbs have become atrophied; barnacles; wheel animalcules; water fleas; moss-polyps, etc. The causes of degeneration are roughly summed up as (1) parasitism; (2) fixity or immobility; (3) vegetative nutrition; and (4) excessive reduction of size.

The inference which I deduce from these facts is, that the origin, duration, and extinction of species have been largely regulated by circumstances outside the organism itself. Why the Pearly Nautilus should survive to the present day, while those huge terrestrial reptiles, the *Dinosauria*, which came into existence at a much later period, have entirely disappeared, is a problem which cannot be easily answered. Are we to suppose that such monsters as the *Atlantosaurus*, which attained a length of over 80 feet and a height of 30 feet, or the *Brontosaurus*, two skeletons of which have been found showing the animal to have been 50 feet in length, or the huge *Iguanodon*, whose semi-erect skeleton stands 14 feet in height, were not able to hold their own in the struggle for life? Several phenomena in the ever-changing environment might be advanced as adequate causes of their extinction; as, for instance, the submergence of extensive areas of land, or the appearance on the scene of better equipped competitors, which would either

kill them, or deprive them of their customary food. That bulk and strength give way to cunning and agility is not peculiar to human activities. The tiger who sees the carcase on which he has just feasted devoured by birds has no power of retaliating on the thieves, because his superior strength cannot be brought into action against his aerial foes.

The result of this brief survey of the organic world, past and present, is to show that while the vast majority of living things have not risen high up in the scale of evolution—some remaining for ages on a comparatively low plane, or even degenerating, and others becoming extinct—there are a few which have made extraordinary advances both as regards differentiation of structure and specialisation in function. That the chronological order in which animals flourished in by-gone ages was from the less to the more highly developed will be apparent by a glance at a table of the stratified rocks, with their typical fossil remains. Starting with the Palæozoic period, and passing in succession through the more recent strata of the earth's crust, we find the sequence in the appearance of the Vertebrata to be—fishes, reptiles, birds, mammals, and man. That is to say, in the Cambrian period only fossils of invertebrate animals are found; in the Devonian we have, in addition to these, remains of fishes; while in the lower Mezozoic we have, together with all the previous forms, those of reptiles. In the Cretaceous period birds and mammals appear for the first time among the inhabitants of the globe, while man, the most highly developed of all, comes on the scene only towards the end of the Tertiaries.

This chronological sequence in the development of animal life has a remarkable parallel in the phenomena of embryology; and this to my mind is a striking proof of the truth of the evolution theory of organic life. In embryology the ultimate visible and starting-point in the development of the animal is the ovum, which is virtually a cell or living corpuscle. So complete is the parallelism observed in the series of changes which take place during fœtal life, and the gradual development of animals into the higher stages of existence, that Häckel formulated the theory, that the develop-

ment of the individual is a recapitulation of the historic evolution of the race to which it belongs. The meaning of this, when applied to man, is that in his embryological stage we have presented to us, in the short space of nine months, the successive phases of his entire career on the globe since he first emerged from his protozoan swaddling clothes. Moreover, in his completed stage he carries with him some vestiges of his ancestral existence. What pregnant truths are embodied in the following remarks of Professor Huxley:—"He (the investigator) also discovers rudimentary teeth, which are never used, in the gums of the young calf and in those of the fœtal whale; insects which never bite have rudimental jaws, and others which never fly have rudimental wings; naturally blind creatures have rudimental eyes; and the halt have rudimentary limbs. So, again, no animal or plant puts on its perfect form at once, but all have to start from the same point, however various the course which each has to pursue. Not only men and horses, and cats and dogs, lobsters and beetles, periwinkles and mussels, but even the very sponges and animalcules, commence their existence under forms which are essentially undistinguishable, and this is true of all the infinite variety of plants. Nay, more, all living beings march, side by side, along the high road of development, and separate the later the more like they are; like people leaving church, who all go down the aisle, but having reached the door, some turn into the parsonage, others go down the village, and others part only in the next parish. A man in his development runs for a little while parallel with, though never passing through, the form of the meanest worm, then travels for a space beside the fish, then journeys along with the bird and the reptile for his fellow-travellers; and only at last, after a brief companionship with the highest of the four-footed and four-handed world, rises into the dignity of pure manhood" ("Collected Essays," vol. ii. p. 5).

By this time you will have gathered, by implication if not by direct statement, that life itself had a beginning, and that this beginning was antecedent to, or at least contemporary with, the earliest geological formations disclosed in the crust

of the earth. The problem which now confronts us is to determine if the chain of organic life can be carried back into the physical and chemical phenomena of the inorganic kingdom. It is well known that the food of plants consists almost entirely of inorganic compounds, *i.e.*, water, carbonic acid, ammonia, together with some minute quantities of mineral matter. On the other hand, the food of animals must contain matter which is the product of some other living organism. In view of this intimate relationship between the recognised phenomena of the animal, vegetable, and mineral kingdoms, one would suppose *primâ facie* that there was little to be bridged over in the transition between the inorganic and organic worlds; but yet, according to the most philosophical minds of the present age, they are separated by an impassable gulf. No biologist has ever yet succeeded in showing experimentally that life can be generated from inorganic materials alone. The law enunciated by Harvey—*omne vivum ex ovo*—is absolutely true so far as the higher animals are concerned; and if it be slightly amplified so as to read *omne vivum ex vivo*—thus covering reproduction by gemmiparous and fissiparous processes—it is true for all living things. Hence it follows that, if this globe were completely sterilised and subsequently replaced in its present environment, life would not again reappear on its surface, unless its germs were imported from some external source. So strongly had this view impressed Lord Kelvin, that in 1871, in his address as President of the British Association, then held in Edinburgh, he could offer no better explanation of the origin of life on this earth than that it was an importation "through moss-grown fragments from the ruins of another world." This hypothesis, says its distinguished author, "may seem wild and visionary; all I maintain is that it is not unscientific." Professor Huxley, just the year before (1870), also in a presidential address at the same Association, while dealing with the same problem, uses the following remarkable words:—"And looking back through the prodigious vista of the past, I find no record of the commencement of life, and therefore I am devoid of any means of forming a definite conclusion as to the conditions

of its appearance. Belief, in the scientific sense of the word, is a serious matter, and needs strong foundations. To say, therefore, in the admitted absence of evidence, that I have any belief as to the mode in which the existing forms of life have originated, would be using words in a wrong sense. But expectation is permissible where belief is not; and if it were given me to look beyond the abyss of geologically recorded time to the still more remote period when the earth was passing through physical and chemical conditions, which it can no more see again than a man can recall his infancy, I should expect to be a witness of the evolution of living protoplasm from not living matter. I should expect to see it appear under forms of great simplicity, endowed, like existing fungi, with the power of determining the formation of new protoplasm from such matters as ammonium carbonates, oxalates and tartrates, alkaline and earthy phosphates, and water, without the aid of light" ("Collected Essays," vol. viii. p. 256).

But whatever be the views held as to the origin of life, all are agreed that its first appearance on the earth was in a very simple garb. Even on Lord Kelvin's hypothesis, the first organisms could hardly be more specialised than the simple cell. On the other hand, according to Professor Huxley, cells would be the result of physico-chemical causes operating for long ages. They were even then advanced organisms compared to molecules and protoplasm, and had already mounted the first rung in the ladder of evolution. When life reached this stage, we can readily conceive that its transmission ever afterwards would be more readily effected by reproduction than by the slow process of physico-chemical action, so that in a short time the latter would be discontinued. Cells propagate so rapidly and in such abundance, that even then there would be a struggle for the available food. Two or more cells would combine, and finding advantage in aggregation, the process would be perpetuated. Thus was initiated the method of construction and elaboration of compound organisms, which has culminated in our day in the infinite variety of plants and animals now inhabiting the globe. If you ask me how these combinations

take place, I am speechless. I do not, however, suppose that they are more mysterious than chemical action. In both we see a rearrangement of the particles of matter in obedience to some fixed laws. So also in embryology, there is a rapid building-up of materials under influences that are common in the organic world, the result of which is to produce animals *nearly* similar to their parents. I emphasise the qualification, because it is on the acknowledged fact that no two animals, even when born of the same parents, are exactly alike, that Mr Darwin founded his famous theory of the origin of species. This genetic source of variation must not be confounded with modifications induced by the environment. I was very much struck by some recent observations on this subject by Professor Sedgewick in his presidential address at the Zoological Section of the British Association at Dover (1899). "Organised beings," he writes, "present, as you are aware, two main kinds of reproduction—the sexual and the asexual. These two kinds of reproduction present certain differences, of which the most important and the only one which concerns us now, is the fact that genetic variation is essentially associated with sexual reproduction, and is rarely, if ever, found in asexual reproduction. In other words, whereas the offspring resulting from asexual reproduction as a rule exactly resemble the parent, they are always different from the parents in sexual reproduction." In illustration of this point, he instances what takes place in the potato-plant. The potato—say Magnum Bonum—can and does normally propagate itself asexually by means of its underground tubers. Now, if you take one of these and plant it, it gives rise to a plant exactly resembling the parent. But if, on the other hand, you try to raise plants from the real seeds which are produced in the flowers, "do you think," asks the professor, "that any of them will be the Magnum Bonum, with all its properties of keeping, resisting diseases, and so forth? Not a bit of it. The probability is that not one of your seedling plants will exactly reproduce the parents." Of course, in the higher animals there is no asexual reproduction, but the point is interesting as showing greater latitude of variation in sexual descent.

There is one other line of thought to which I should like to direct attention, and that is the correspondence which exists between the senses and the environment. Animals, as you are all aware, keep up their connection with the external world by means of five senses, which are not inappropriately designated the five gateways of knowledge. The media through which these senses operate are more or less elaborately constructed organs—the degree of elaboration being generally in proportion to the position of the species in the scale of development—ranging from the merest grouping of a few nerve-cells up to the complex mechanism of the brain and nervous system of the higher vertebrates. Now, what I wish to point out here more particularly is the fact that these different senses have extremely well-defined counterparts in the external world, in the form of light, atmospheric undulations, and certain physical and chemical properties of matter, so that every sense has its special excitant to which it responds.

Among the Protozoa there is great irregularity in the degree of development of the senses, some having no localised organs, and others only rudimentary ones. The majority of the molluscs are endowed with the sense of smell, and some landshells are guided to their food by taste as well. The cephalopods and gastropods are furnished with visual organs, while most of the bivalves are without them.

The natural phenomena, to which the senses are thus so remarkably correlated, may be regarded as constant quantities in nature, and hence they produce cumulative effects on living organisms susceptible to improvement or advance in life. Altogether, they present an ideal field for the action of natural selection as defined by Mr Darwin. The same arguments apply to many of the mechanical contrivances by means of which animals have accommodated themselves to their physical surroundings. Locomotion by land, air, or water was effected in each case by appropriate appliances, so that the teleological argument for design in the organic world resolves itself into the slow processes of harmonising means with ends, by the adjustment of small increments of variation extending over long periods of time.

It will now become apparent that it is no easy task to trace the direct line of the ascent of man, from a low unicellular organism up to his present position of superiority over his fellow-creatures. On the earlier stages of the general advance of life, Professor Cleland makes the following pertinent remarks:—

"We pass from masses indeterminate and spheroidal in shape, minute beings moving in water, barely visible, or seen only with the microscope, mere isolated living corpuscles, beings scarcely, if at all, exhibiting separate organs, to others more elongated, with the mouth towards one extremity, which, in the event of the animal being fixed like a plant, is the extremity standing out free in the water, and in the event of its moving about, is placed foremost, so as to come in contact with food as it moves along. Then, in such an animal, when not fixed but moving from place to place, there is one surface turned to the ground and another toward the light, and having therefore very different relations. Thus, you observe that in the mere surroundings of animals of the simplest kinds there is a rationale and an excitant to be found for the origin, first of starry or cylindrical symmetry out of the original egg shape, then for the origin of a head and a tail end, and subsequently of a ventral and a dorsal aspect, with, as a consequence, so long as the growth is equal, bi-lateral symmetry, or a right and a left side. I may add that any advantage of one side over the other in growth would turn the body to one side, and, by being continued, originate a spiral—a form which abounds in the animal kingdom. Another series of complications sets in, connected with the relation of different parts to the surface. The superficial part, coming into relation with the world around, becomes what Bichât called the *animal sphere*, devoted to sensation and locomotion; while the deep part round the digestive cavity becomes separated as the *vegetal sphere*, and the body-cavity makes its appearance between.

"As the axis of the animal further elongates, we next find the phenomenon called *segmentation* developing, that is to say, a repetition of similar parts in linear series, producing the sort of arrangement with which every one is to some

extent familiar in a centiped. In this segmentation I have latterly learned to recognise a mere modification of that process of complete division by means of which the simpler organisms multiply,—a process in which a whole individual breaks up into parts, and each portion receives the potentialities previously inherent in the individual parent mass. Such segmentation as this is not only found in all the groups which have ringed bodies, or have their limbs arranged in pairs, but is the mode in which the bones, muscles, and nerves, in fact the animal sphere of vertebrates up to man, make their first appearance" (*Journal of Anatomy and Physiology*, vol. xviii. p. 348).

The further advance of man's ancestors is supposed to be from some low fish form, then successively through amphibians, reptiles, and mammals. It is probable that in all these progressive stages there were numerous concurrent species, each more or less divergent in structure, so that it is almost impossible to ascertain which of them supplied the real line of his ascent. Between reptiles and birds numerous intermediate links have been found, such as Pterodactyles, *Archæopteryx*, *Hesperornis*, etc., but between reptiles and mammals the connection is very obscure. Indeed, some palæontologists maintain that the immediate ancestors of the Mammalia were not the Reptilia, but some unknown Amphibian form. I will not detain you by further speculations on the line of man's ascent, more than to say that, among living animals, the orang, the chimpanzee, and the gorilla are the nearest to him both in somatic structure and mental endowments. It would, however, be contrary to all the known facts of evolution to suppose that he has sprung from any of these animals. But, on the other hand, there can be little doubt that, were we able to trace his pedigree far enough back, we would encounter a species which was a common ancestor to him and one or other of the anthropoid apes. The morphological difference between man and his nearest of kin is comparatively little, certainly not so great as that between a tiger and a horse; but yet the mental capacity of the former is so far above that of any other animal, that many thoughtful men of the present day deny

the possibility of bridging over the gap by any biological processes whatever. This is the problem we have now to consider.

During the æons that have rolled past since life began on the globe, we have seen how myriads of generations of animals came into existence, flourished for a time, propagated their kind, and then vanished for ever. Glimpses of these evanescent life-panoramas show streams of varied beings, arranged in groups, and each group possessing characters admirably adapted for making the best use of certain conditions in their environments. They were provided with special means for attack and defence, and for procuring the necessities of life. Some birds and insects had their bodies transformed into flying machines, not, however, always on the same plan. For example, the Pterodactyle had its fore-limbs modified so as to be used, partly as prehensile organs, and partly as wings. It had three of its fingers on each limb free and furnished with claws, while the fourth was enormously elongated, in order to support the outer edge of a sail-like membrane which, on the inner side, was attached to the arm, body, hind limb, and tail. On the other hand, the Archæopteryx, though differing very much from the birds of the present day, had large feathers on its wings and tail, and its feet were similar to those of modern perching birds. Again, some air-breathers reverted to an aquatic life, as the whales and seals; and their limbs, which had been previously adapted for locomotion on land, were converted into paddle-like flappers for propulsion in water. But, with respect to the air-breathing organ, a remarkable fact is to be noted. Although these animals were actually descendants from aquatic ancestors possessed of gills, it was entirely beyond the power of nature to retrace her own evolutionary steps and restore them their lost gills. And hence, these animals have had ever since to come to the surface at stated intervals to breathe. Animals when they get on definite lines have not the power of reconsidering their position. They are impelled, as it were by a *vis a tergo*, to pursue their course on the selected path, subject only to modifications

possible within the lines adopted. For example, no conceivable morphological change on the foot of a horse could improve it as a means of locomotion, on the plan by which the animal has achieved its special position in the organic world, *i.e.*, by gradually lengthening and strengthening the bones of one of the original five toes, and dispensing with the others. If hard pressed and beaten in swiftness by more powerful enemies, extinction would be its fate unless it resorted to some other means of protection. It is another of Professor Cleland's terminal forms of life. Then again, some animals find security by burrowing in the earth, and others by climbing trees. Some fight the battle of life with claws, and others with great sharp-pointed teeth. Even an elongated neck or a protruding nose may be the straw which turns the scales in favour of the particular mode of existence the animal has selected. Indeed, there is scarcely a physical, chemical, mechanical, protective, or aggressive principle invented by man which has not been utilised in the armoury of the organic world. But it is not on any such lines that man's advance has been based.

I have already noted the fact that the superiority of man over other animals is due to his higher mental organisation. I do not say that man has a monopoly of the reasoning faculty, except perhaps in dealing with abstract ideas, and that he alone can draw conclusions from physical phenomena, for many animals do this. They have learned by experience to interpret the ordinary phenomena of nature and to conform to their behests. But their intelligence, whether instinctive, *i.e.*, hereditarily acquired, or suddenly elicited by current phenomena, is altogether on a lower platform than that of man; and its manifestations are very much alike in them all, seldom going beyond the power of recognising what is beneficial or injurious to the individual. This limitation in the mental capacity of animals, except man, is determined by the uniformity of cause and effect in the material world, the interpretation of which involves no higher reasoning than simple obedience to physical laws. But in the case of man a new element is superadded. Man is not content with the supply of fruits he gathers from the

garden of Nature, nor with the precariousness of the showers of heaven which water them. He plants his own vineyard, and waters it if necessary. He not only recognises the physical cause of a given effect, but often adjusts the cause so as to produce the effect. Instead of being entirely controlled by nature, he, to a large extent, controls the operations of nature, or takes means to counteract them. In short, he reasons both by induction and deduction. The primary step which enabled *Homo sapiens* to shoot up so conspicuously above all his fellow-creatures was very simple, probably a pure accident due to some change in the environment. For some reason or other one of the semi-erect Quadrumana of the Tertiary period, probably of arboreal habits, took to walking on his hind legs. The fore limbs, being thus set free from taking part in the work of locomotion and the support of the body, were henceforth exclusively used as manipulative organs, or hands. Bipedal locomotion was, of itself, an insignificant change, displaying less mechanical ingenuity than the flying apparatus of the Pterodactyle. Nor was it an innovation on the evolutionary processes previously in vogue in the animal world, as any one must acknowledge who has watched the firm and dignified mien of that comical looking creature, the Penguin, now in the Zoological Gardens in London, as he makes his bipedal perambulations around his premises. The new element consequent on the attainment of the erect attitude by man, was the use to which the hands were put. By substituting for Nature's appliances, implements, weapons, and tools made by his own hands, new stimulants for thought were brought on the stage of life, the consequences of which were profound and far-reaching. Thus man may be distinguished from all other animals by the fact that he alone can manufacture and use tools skilfully. Having elsewhere ("Prehistoric Problems," chap. ii.) discussed the influence which the attainment of the erect posture, with its concomitant morphological changes, had on the intellectual development of man, I need not here pursue this part of the subject.

The Biblical account of the creation of the world and the

fall of man has exercised the minds of the most eminent philosophers, scientists, and religionists of this century. Although the attempt to reconcile its details with the known facts of Zoology and Palæontology has failed, yet I am not convinced that the story is a myth. We must bear in mind that the doctrine of evolution was known as a speculation to the early inhabitants of India, Babylonia, and the eastern shores of the Mediterranean, long before the writer in Genesis penned his memorable narrative; and it seems to me that he has blended these current speculations with the specific acts of creation therein recorded. By distributing the work over five consecutive days, a definite chronological sequence is affirmed, which, to my mind, gives an evolutionary character to the corresponding acts of creation. On the supposition that these days represent vast periods of time, some critics maintain that the order in which animal life is made to appear corresponds to that disclosed by palæontological researches. Mr Gladstone, in his famous controversy with Professor Huxley on this subject (*Nineteenth Century*, 1885–86), thus tabulates the chronological sequence of events as deduced from the Biblical narrative:—

(1) A period of land anterior to all life.
(2) A period of vegetable life anterior to animal life.
(3) A period of animal life in the order of fishes.
(4) Another stage of animal life in the order of birds.
(5) Another in the order of beasts.
(6) Last of all man.

It need hardly be said that the above sequence is not in precise harmony with the facts of palæontology, for any tyro can see that, from the standpoint of evolution, land-quadrupeds must have preceded birds—a statement which is also proved to be a fact by direct evidence. But although this and some other details are decidedly out of joint, I think the *tout ensemble* could only emanate from the brain of one who had some glimmering of the doctrine of evolution.

The portion of the narrative bearing on the creation of man can only be seriously considered as an allegory;

and as such, I fancy, we can see in its main statements a remarkable coincidence with the facts of evolution. The upright posture, which is the most outstanding feature in man's physical appearance, could not fail to be signalised as one of great dignity, seeing that it was the "image and likeness" of God. The act of disobedience in eating of the fruit of the Tree of Knowledge of Good and Evil, though it secured to him the divine prerogative of wisdom, opened his eyes also to the momentous fact that he was henceforth a moral and responsible being.

Thus, on our first acquaintance with man, we find him possessed of exceptional qualities, viz., the erect attitude, and the power of discerning between good and evil (which, of course, entails moral responsibility)—qualities which may be truly characterised as heaven-born. But whatever difference of opinion may exist as to the means by which these qualities were acquired, they are pointedly held up both in the Biblical allegory and in the teachings of evolution as the most distinguishing attributes of humanity. With such endowments and the co-operation of the forces of nature, he has nobly fulfilled the trust assigned to him as lord over the animal world. Already he has converted the greater portion of the earth's surface into a veritable garden, and to a large extent he determines what animals shall live and what plants shall grow. As to his future prospects, it may be asked if he too is "a terminal form of life," comparable to a tiny stream which gathers strength and volume as it hurries along, now turbulent, now placid, then lost in the boundless ocean? Who can tell! Impenetrable darkness broods over the horizon whichever way we look, and the only certainty which lies within the radius of our limited vision is the continued expansion and progressiveness of human civilisation.

XX. *Results of Meteorological Observations taken in Edinburgh during* 1899. By R. C. MOSSMAN, F.R.S.E., F.R.Met.Soc.

(Read 21st February 1900.)

The observations discussed in this paper are deduced from readings of the standard instruments made daily at 9 A.M. and 9 P.M., the values thus obtained being checked by comparison with the automatic records from the barograph, thermograph, and hygrograph, as described in previous reports. The station was inspected on September 18th by Dr Buchan, and everything found in good order, except that the maximum thermometer was reading 0°·4 too low. As the instrument agreed with the inspector's standard in the autumn of 1898, I have assumed the error to be a progressive one, the correction applied being 0°·1 for the last three months of 1898, and 0°·2, 0°·3, and 0°·4 for each succeeding quarter of 1899. The values given in the tables for the first nine months of last year will accordingly be found to differ slightly from the returns supplied to the Registrar-General for Scotland, and published in his weekly, monthly, and quarterly reports. The columns affected are those giving the absolute maximum, mean maximum, mean daily range, and monthly range of temperature. Since September the error has remained constant at 0°·4. The instrument in question has been in use since June 1887, and has hitherto agreed with the standard thermometer of the inspector. All the thermometers employed, it may be said, are engine divided on the stem and have Kew certificates.

During the year the instruments in use have been the same as formerly, the only addition being one of Stevenson's cloud-reflecting compasses for determining the movement of clouds.

The kite-flying experiments referred to in last report have been continued, with the able assistance of Mr Anderson and Mr Lonie. About fifteen flights were made from a temporary station in the vicinity of Leadburn, 17 miles south of Edinburgh. The meteorograph has not yet been

sent up, as several improvements in the kite apparatus are still required, before this costly instrument can be used with safety. On several occasions friction gradually sawed through the cord fastenings which connect the kite with the piano wire, the result being that the kite broke loose and floated through the air for several miles before reaching the ground. An elastic bridle has been devised to relieve the strain on the connections during squalls, and several other improvements have been effected. The partial failure of some of the experiments is to be largely attributed to the strong winds that prevailed during several of the ascensions. The work will be resumed at an early date; and arrangements are in progress for the equipment of a meteorological base station at Leadburn.

Remarks on the Meteorology of 1899.

January.—The weather of January was very mild till the 22nd, with strong south-west winds and much rain. During this period only 13 hours sunshine was registered, and there were only three days without rain. The last nine days were cold and dry, with a good deal of sunshine, although fog was recorded on the 25th and 28th. The mean temperature of the month was 1°·3, and rainfall 52 per cent., above the average. Sleet fell on the 12th, and snow on the 16th.

February.—During February nearly all the meteorological elements agreed closely with their normals for the time of year, the only marked departure from the average being a deficiency of rainfall, nearly all of which fell between the 6th and 18th. Wintry conditions were almost wholly absent, the only cold spell experienced being from the 4th to the 7th, and after the 21st. A little snow fell on the 5th, and again on the 7th. There was a dense mist on the 26th and 27th; the unusual phenomenon of a silver thaw, or rain falling with a temperature below freezing point, being recorded on the evening of the 26th. This phenomenon takes place when a warm wind sets in at a short distance from the earth's surface. The rain has not time to become frozen in the shallow section of cold air in immediate contact with the ground, the temperature of which is

exceedingly low. The moisture on reaching the ground consequently freezes, and covers all objects with a sheet of ice. It almost invariably precedes a thaw. Auroras were seen on the 12th and 23rd.

March.—Mild weather prevailed during the first eighteen days of the month, but from the 19th to the 25th a very cold spell was experienced, the mean temperature for this period being 32°·6, or 13°·8 below that for the week immediately preceding, and 8°·6 below the average. Reference to the Edinburgh weather records for the last forty-two years shows that only once before has such a cold week been experienced so far on in the year, viz., in 1879, when the mean temperature of the seven days ending March 28th was 32°·0. The soil was frozen to a depth of between 3 and 4 inches from the 21st to the 24th inclusive. In spite of brilliant sunshine, the temperature during the day kept very low, the maximum ranging from 35°·9 to 42°·0. An aurora was seen on the 21st, and a heavy fall of snow took place on the 25th. No rain or snow fell during the fifteen days ending with the 22nd. Sunshine and precipitation were normal, but pressure and temperature were both in excess of the average.

April.—During April, temperature, rainfall, sunshine, and humidity were in close agreement with the normal, but pressure was considerably below the average. A noteworthy feature was the unusual sunlessness of the afternoons. Thus of 111 hours sunshine registered, 74 hours took place before noon, but only 37 hours, or half the quantity, in the afternoon hours. No warm weather was experienced, but, on the other hand, there was a marked absence of the inclement conditions that so often prevail at this time of year. Rain fell frequently, there never being more than three consecutive days without some. A gale was experienced on the 4th, and snow fell on the 17th.

May.—Very fine, sunny, although cold weather prevailed from the 3rd to the 8th, the bright sunshine recorded amounting to 70 per cent. of the total possible. From the 9th to the 23rd, weather of the most cheerless kind prevailed, the temperature being low, sunshine very deficient, and the

rainfall excessive. During this period only 35 hours sunshine was recorded, of which 20 hours occurred on the 16th and 17th, leaving an average of barely an hour a day for the remainder of the time under consideration. Close on two inches of rain fell on the 18th and 19th, the fall on the latter day amounting to 1·25 inch. Reference to daily rainfall observations taken since 1854 shows only one instance of a heavier rainfall in May, viz., in 1865, when, on the 30th of the month, there fell 1·29 inch. On May 15th, 1872, 1·10 inch of rain fell, and on May 7th, 1882, 1·20 inch, there being thus only four rainfalls exceeding one inch during the last 45 years in the month of May. The weather improved steadily after the 23rd, the last eight days being rainless, with a good deal of sunshine and a steadily rising temperature.

June.—The weather of June was of two distinct types, the first seventeen days being warm, sunny, and rainless, and the remainder of the month cool, dull, and with a considerable downfall. There was no rain between May 24th and June 17th, a period of 25 days, the drought being the most severe since the summer of 1869, when there was a spell of 29 days without rain. The mean temperature was 2°·5 above, and the rainfall two-thirds of the average. There was a fog on the 21st, and thunder was heard on the 28th.

July.—The characteristic features of the weather of July were a rather high temperature and pressure, deficit of sunshine, and a slight excess of rainfall. The month opened with a heavy rainstorm from the N.E., the rainfall for the first two days being 2·11 inches. In the hour ending 1.45 P.M. on the 2nd, half an inch of rain fell during a slight thunderstorm. Another heavy downpour, amounting to three-quarters of an inch, occurred on the 12th between 1 and 4 P.M., during a sharp thunderstorm. A dense wetting mist with an easterly wind preceded the phenomenon. There was throughout the month a complete absence of fine settled weather, the 13th and 31st being the only days with more than 70 per cent. of the total possible sunshine, while on eight days no sunshine was recorded. Barometric pressure was much above the average, and the excess of temperature was entirely due to the unusual nocturnal warmth, the mean of the day values being

the normal. The month closed with high temperatures, the maximum on the 30th being 76°·9, and on the 31st 78°·4.

August.—The weather of August was of a phenomenal character, less than a quarter of an inch of rain being recorded during the first four weeks. A heavy downfall on the 29th raised the total for the month to 0·55 inch. August 1880 had exactly the same rainfall, but to find an August with a smaller rainfall we have to go back to 1796, when the precipitation was only 0·45 inch. The mean temperature was 61°·7, or 3°·9 above the average; the excess being more marked during the day than at night, the days being 5°·0, but the nights only 3°·1 in excess of the normal. The only warmer Augusts since 1764 were those of 1819, 1780, and 1779. The mean of all the maxima was 70°·0, being the highest on record during the last sixty years, for which detailed statistics are available. As regards other months, the above value was exceeded only in June 1846, and in the Julys of 1847 and 1868. The highest shade temperature was 83°·1, on the 24th, a value only twice exceeded since 1840, viz., in the Augusts of 1868 and 1893, when the temperature rose to 87°·7 and 84°·0 respectively. The mean barometric pressure was also unusually high, being exceeded since 1770 only in the years 1864, 1818, 1801, 1780, and 1779. The mean pressure was highest, 30·138 inches, in 1864, as against 30·082 inches in 1899. A noticeable feature of the meteorology of the period under review was the extreme stillness of the air, no less than 20 of the 62 wind observations, made at 9 A.M. and 9 P.M., being entered as calm. April 1862 had 22 calms entered at the time of the bi-daily observations, and September 1838 had 20 entries, these being the only months since 1764 with as many calms as in the month under consideration. Judging from the barometric readings and the wind observations, it is evident that the British Isles were under the influence of a vast anti-cyclone, which is usually central at this season about lat. 35° N., long. 42° W., but which, from some cause at present unexplainable, was in August 1899 shifted over 1000 miles north-east of its usual position.

September.—The weather of September was wet and

unsettled, although there were only two days without bright sunshine. Pressure throughout the month continued low, there being an almost complete absence of anti-cyclonic conditions. During the first eleven days there was a continuance of the abnormal warmth of August; thereafter, until the 20th, conditions were about normal, but the last ten days of the month were decidedly cold for the season. A sharp thunderstorm was experienced on the 29th with heavy rain and hail, and the last day of the month proved the wettest of the whole year, with a rainfall of 1·38 inch in the 24 hours.

October.—October was characterised by high temperature and pressure, accompanied by a rainfall only half the average. Sunshine was normal, and mean relative humidity decidedly below the average. A dry, warm, and sunny period prevailed from the 13th to the 24th, during which temperature rose to the unusual height of 67°·4 on the 19th, this value being 15° in excess of the normal for the season. There was a south-west gale with strong squalls on the 29th, and a thunderstorm with heavy rain and hail at 7.35 P.M. on the 30th. Showers of hail also fell on the 13th.

November.—The outstanding feature of the weather of November was the extraordinary mildness of the air, the mean temperature being 47°·4, or 6°·5 above the average. This is absolutely the highest mean temperature on record for November during the last 135 years, the next highest occurring in 1818, when the mean was 46°·7. An examination of the daily temperature observations shows that the maximum exceeded 50° on twenty-three days, while on no occasion was frost registered in the screen four feet above grass. The month opened with very stormy weather, the rainfall on the 2nd slightly exceeding an inch. Unsettled conditions continued till the middle of the month, the second half of which was on the whole fair and dry, with a high barometer. No fogs were experienced, but bright sunshine was below the normal. As regards the other elements, pressure and rainfall were above the average. Relative humidity was 5 per cent. below the mean. The winds of the month blew almost wholly from the west and south-west.

December.—The mean temperature of December was in marked contrast to that of November, the records showing a fall of 11°·5 between the two months, being the largest observed during the last 135 years. The nearest approach to this large fall was in 1846, when December was 10°·3 colder than the preceding month. There was a sharp spell of frost from the 9th to the 15th, and again from the 26th to the 28th. Snow fell on the 10th, 11th, 22nd, and 28th, the fall on the 11th being heavy. The air throughout the month was singularly calm, no gales being reported. Even on the 29th, when the barometer fell to the low level of 28·456 inches, the wind did not exceed a fresh breeze. Dull weather predominated, no less than twenty-one days being sunless. Up to the 23rd only 5 hours sunshine was recorded, no less than eighteen days in this period being sunless. On many of these days there was great gloom, owing to the denseness and low elevation of the clouds.

Noteworthy Phenomena in the Meteorology of 1899.

Highest barometric reading 30·772 inches, on January 26th.
Lowest barometric reading 28·456 inches, on December 30th.
Highest temperature in shade 83°·1, on August 24th.
Lowest temperature in shade 18°·3, on December 15th.
Greatest range of temperature 31°·9, on June 12th.
Least range of temperature 2°·5, on December 31st.
Highest temperature in sun's rays (black bulb thermometer in *vacuo*) 132°·9, on August 11th.
Greatest excess of sun maximum over shade maximum 68°·8, on June 24th.
Lowest temperature on grass 10°·0, on December 15th and 16th.
Greatest difference between minimum on grass and in shade 10°·1, on December 12th and 14th.
Sunniest day May 27th, with 13 hours 28 minutes bright sunshine, being 80 per cent. of the total possible.
Greatest daily rainfall 1·38 inch, on September 30th.

	Barometer at 32° and Mean Sea-Level.						Temperature in Shade 4 Feet above Grass.															
																	Departure from Average 50 years.					
	Highest in Month.	Lowest in Month.	Monthly Range.	Difference from Average 1840–1896.	Mean Pressure.	Difference from Average 1770–1896.	Highest in Month.	Lowest in Month.	Monthly Range.	Mean Temperature.	Mean of all the Highest.	Mean of all the Lowest.	Mean Daily Range.	Greatest Daily Range.	Least Daily Range.	Mean Variability of Temperature.	Mean Max.	Mean Min.	Mean Daily Range.	Mean Temp.	Mean Variability of Temp. 57 years.	Diff. from Aver. 1764-1896, Mean Temp.
	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°
January,	30·772	28·701	2·071	+ ·460	29·680	− ·136	51·7	22·0	29·7	38·2	42·9	33·5	9·4	23·3	3·2	3·4	+0·2	+0·7	−0·5	+0·4	+0·2	+1·4
February,	30·498	28·817	1·681	+ ·244	29·795	− ·018	54·1	22·1	32·0	39·6	44·8	34·4	10·4	24·0	3·8	3·2	+0·5	+0·6	−0·1	+0·5	+0·3	+1·3
March,	30·503	28·925	1·578	+ ·160	29·961	+ ·097	63·1	23·5	39·6	41·6	46·9	36·3	10·6	25·4	4·2	3·5	0·0	+1·9	−1·9	+1·0	+0·7	+1·3
April,	30·219	29·099	1·120	− ·090	29·736	− ·159	61·5	28·5	33·0	44·0	50·5	37·5	13·0	28·5	3·9	3·0	−1·5	−0·1	−1·4	−0·8	+0·3	−0·8
May,	30·570	29·269	1·301	+ ·224	30·033	+ ·093	71·1	33·2	37·9	47·0	53·3	40·7	12·6	25·2	2·6	2·1	−4·4	−1·4	−3·0	−2·9	−2·9	−0·7
June,	30·521	29·489	1·032	+ ·097	30·057	+ ·125	79·9	44·1	35·8	58·4	66·4	50·4	16·0	31·8	2·9	3·2	+2·8	+2·6	+0·2	+2·6	+0·4	+2·7
July,	30·429	29·366	1·063	+ ·128	30·024	+ ·148	78·4	48·0	30·4	59·9	66·0	53·8	12·2	24·2	3·3	2·2	+0·4	+3·2	−2·8	+1·8	−0·3	+1·3
August,	30·314	29·566	0·748	− ·251	30·082	+ ·207	83·1	47·0	36·1	61·7	70·0	53·4	16·6	28·5	3·8	2·5	+5·0	+3·1	+1·9	+4·1	0·0	+3·9
September,	30·187	29·100	1·087	− ·086	29·724	− ·154	69·1	37·2	31·9	54·0	60·7	47·3	13·4	22·0	6·2	2·5	−0·3	+0·3	+0·6	0·0	−0·1	+0·4
October,	30·486	29·344	1·142	− ·339	29·956	+ ·146	67·4	32·2	35·2	49·1	55·7	42·5	13·2	23·6	3·3	3·4	+2·6	+1·1	+1·5	+1·9	+0·5	+1·9
November,	30·712	28·640	2·072	+ ·506	29·944	+ ·143	59·3	33·5	25·8	47·4	52·0	42·8	9·2	17·4	3·2	3·2	+5·2	+6·3	−1·1	+5·8	+0·1	+6·5
December,	30·469	28·456	2·013	+ ·455	29·830	+ ·030	53·3	18·3	35·0	35·9	40·1	31·7	8·4	19·2	2·5	3·2	−3·7	−2·4	−1·3	−3·0	0·0	−2·4
Year,	30·772	28·456	2·316	...	29·902	+ ·044	83·1	18·3	64·8	48·0	54·1	42·0	12·1	31·8	2·5	3·0	+0·6	+1·3	−0·7	+0·9	+0·2	+1·2

	Rainfall.					Relative Humidity. Saturation=100.				Vapour Pressure.			Dew Point.			Solar and Terrestrial Radiation.							
	Total Fall.	Diff. from Average 122 years.	Max. in 24 hours.	No. of days on which ·01 in. or more fell.	Diff. from Average 1877–1896.	Mean at 9 A.M.	Mean at 9 P.M.	Mean, 9 A.M. and 9 P.M.	Diff. from Average 1862–1896.	At 9 A.M.	At 9 P.M.	Mean.	At 9 A.M.	At 9 P.M.	Mean.	Maximum in Sun.	Mean.	Greatest Excess over Shade Maximum.	Average Excess over Shade Maximum.	Minimum on Grass.	Mean.	Greatest Difference from Shade Min.	Mean Difference from Shade Min.
	Ins.	Ins.	Ins.	Days.	Days.	%	%	%	%	In.	In.	In.	°	°	°	°	°	°	°	°	°	°	°
January, .	3·69	+1·26	0·62	21	+5	84·9	83·6	84·2	−2·6	·189	·198	·193	32·4	33·6	33·0	78·3	55·9	33·2	13·0	19·3	30·9	5·7	2·6
February, .	1·45	−0·51	0·31	11	−3	83·5	82·5	83·0	−3·4	·193	·204	·198	33·0	34·5	33·8	101·9	70·2	48·6	25·4	23·0	30·9	6·5	3·5
March, . .	2·13	+0·15	0·58	12	−3	78·2	80·6	79·4	−4·7	·204	·209	·206	34·1	34·9	34·5	101·2	82·4	54·2	35·5	20·0	32·9	6·6	3·4
April, . .	2·29	+0·23	0·32	19	+5	78·6	79·6	79·2	−1·3	·242	·224	·233	38·8	37·1	37·9	112·2	92·0	61·8	41·5	23·0	34·6	7·0	2·9
May, . . .	3·80	+1·71	1·25	15	+1	77·2	83·2	80·2	+2·1	·257	·250	·254	40·7	40·1	40·4	120·9	104·6	65·2	51·3	31·5	38·7	5·2	2·0
June, . . .	1·48	−0·62	0·43	8	−6	72·9	80·1	76·5	−0·9	·381	·357	·369	51·3	49·5	50·4	137·1	112·7	68·8	46·3	40·2	48·6	5·3	1·8
July, . . .	3·98	+0·62	1·24	15	−3	77·3	80·5	78·9	−0·2	·424	·422	·423	54·3	54·1	54·2	130·0	108·4	64·3	42·4	46·3	51·9	3·6	1·9
August, . .	0·55	−2·93	0·28	8	−11	79·4	83·6	81·5	−0·0	·433	·424	·428	54·8	54·1	54·4	129·8	112·6	58·3	42·6	44·5	51·2	5·0	2·2
September, .	3·78	+0·86	1·38	24	+8	80·3	80·5	80·4	−2·2	·331	·312	·322	47·3	45·6	46·4	122·1	102·7	54·5	41·6	33·5	44·2	7·1	3·1
October, . .	1·59	−0·81	0·48	13	−4	82·4	82·2	82·3	−3·5	·279	·278	·278	42·6	42·5	42·6	109·8	87·4	50·6	31·3	23·4	38·4	8·8	4·1
November, .	3·26	+0·62	1·01	16	−1	80·9	82·1	81·5	−5·3	·265	·272	·268	41·5	42·1	41·8	104·0	73·5	44·7	21·1	28·9	40·2	5·2	2·6
December, .	2·13	−0·35	0·41	16	0	83·9	84·5	84·2	−2·2	·179	·186	·183	30·9	32·0	31·5	69·3	47·4	23·9	7·3	10·0	28·4	10·1	3·3
Year, . . .	30·13	+0·23	1·38	178	−12	80·8	81·9	81·4	−1·6	·281	·278	·280	41·8	41·7	41·8	137·1	87·5	68·8	34·0	10·0	39·2	10·1	2·8

	Bright Sunshine for Hour ending Greenwich Time.																Total.	Percentage of possible Duration.	Difference from Average 30 years.	Greatest Percentage of possible in 1 Day.	No. of Sunless Days.	Difference from Average 30 years.	Cloud 0–10.			Mean Wind Velocity per hour.
	A.M.								P.M.																	
	5	6	7	8	9	10	11	Noon.	1	2	3	4	5	6	7	8							9 A.M.	9 P.M.	Mean.	
	Hrs.	Hrs.	Hrs.	Hrs.	Hrs.	Hrs.	Hrs.	Hrs.	Hrs.	Hrs.	Hrs.	Hrs.	Hrs.	Hrs.	Hrs.	Hrs.	Hrs.	%	%	%						Mls.
January,	...	...	...	...	...	...	1·5	5·8	6·9	7·4	4·7	0·9	...	...	...	...	27·2	12	− 9	62	15	+ 4	7·6	5·7	6·6	5·9
February,	...	...	...	...	1·3	6·3	11·8	11·1	10·3	10·0	7·0	2·8	...	...	...	...	60·6	23	− 3	68	8	+ 3	6·9	4·8	5·8	5·4
March,	...	...	0·2	4·6	9·8	13·7	12·2	13·5	11·2	10·2	8·1	7·4	4·8	1·4	...	...	97·1	27	− 3	71	6	− 2	7·3	5·7	6·5	8·9
April,	...	1·2	9·0	10·2	14·2	13·4	14·1	11·7	9·0	6·8	6·1	6·6	5·2	3·2	0·3	...	111·0	27	− 3	71	8	+ 3	6·8	7·6	7·2	6·3
May,	0·8	7·5	10·3	11·7	14·3	15·8	14·2	12·6	14·0	11·7	12·5	13·0	11·4	11·1	4·6	...	165·5	33	+ 1	84	9	+ 5	7·1	6·2	6·6	6·0
June	1·4	6·4	10·6	10·2	9·2	14·0	11·9	13·0	11·7	10·3	11·3	12·2	12·2	10·7	6·5	1·7	153·3	29	+ 1	76	7	+ 4	7·5	5·9	6·7	5·3
July,	0·4	5·1	6·2	8·3	8·5	9·0	10·1	8·1	10·1	9·2	8·2	8·1	8·5	10·3	6·7	1·3	118·1	22	− 7	79	8	+ 4	8·6	7·6	8·1	5·9
August,	...	1·2	6·7	12·4	14·2	13·8	14·8	15·0	16·2	14·8	16·4	14·2	12·9	9·1	2·9	0·5	165·1	36	+ 6	78	5	0	6·2	6·2	6·2	3·3
September,	...	...	0·6	4·7	7·5	7·8	11·4	11·0	9·8	11·8	12·0	9·2	10·5	5·8	1·6	...	103·7	27	− 4	69	2	− 2	8·1	4·6	6·4	7·0
October,	...	...	...	0·2	4·6	9·6	10·4	13·5	11·7	13·9	11·3	8·7	1·0	...	...	...	84·9	26	− 3	75	6	− 1	5·8	5·0	5·4	7·0
November,	...	...	...	...	...	1·5	7·4	9·4	9·7	7·6	5·1	2·2	...	...	...	...	42·9	18	− 6	72	12	+ 3	7·6	7·0	7·3	11·3
December,	...	...	...	...	...	...	0·1	3·8	4·7	2·7	0·8	...	...	...	...	...	12·1	6	− 13	45	21	+ 7	7·8	7·0	7·4	4·7
Year,	2·6	21·4	43·6	62·3	83·6	104·9	119·9	128·5	125·3	116·4	103·5	85·3	66·5	51·6	22·6	3·5	1141·5	25	− 2	84	107	+ 28	7·3	6·1	6·7	6·4

Wind from Observations made at 9 A.M. *and* 9 P.M. *Number of Days it blew from certain directions.*

	N.	N.E.	E.	S.E.	S.	S.W.	W.	N.W.	Calm or Variable.
January,	0	1	3	1	2	5	15	1	3
February,	1	0	4	2	2	2	11	1	5
March,	2	0	2	2	0	1	18	2	4
April,	3	2	6	1	3	1	7	4	3
May,	1	2	17	2	0	0	6	1	2
June,	0	2	11	2	1	1	10	1	2
July,	1	1	5	2	1	1	17	2	1
August,	1	1	9	1	1	1	6	1	10
September,	0	1	1	0	0	0	23	2	3
October,	1	1	2	3	1	4	11	4	4
November,	0	1	1	0	2	6	17	2	1
December,	0	0	4	4	5	0	7	3	8
Year,	10	12	65	20	18	22	148	24	46
Per cent.,	3	3	18	6	5	6	40	7	12
Difference from Average 1764-1896,	−1	−4	0	+1	0	−9	+5	0	+8

Number of Times the following Phenomena were observed.

	Gales.	Halos.	Thunder-storms.	Lightning only.	Auroras.	Snow.	Hail.	Frost in Shade.	Frost on Grass.	Mist or Fog.	Dew.	Hoar Frost.	Rainbows.
January,	0	1	0	0	0	3	0	9	15	0	0	6	0
February,	0	2	0	0	2	2	0	11	18	3	0	7	1
March,	1	3	0	0	1	5	2	8	14	0	2	2	0
April,	1	6	0	0	0	1	1	5	13	0	0	1	0
May,	0	0	0	0	0	0	1	0	3	1	3	1	1
June,	0	0	1	0	0	0	0	0	0	1	0	0	0
July,	0	0	3	0	0	0	0	0	0	0	1	0	0
August,	0	0	1	0	0	0	0	0	0	2	3	0	0
September,	1	1	1	1	0	0	2	0	0	0	0	0	0
October,	1	2	1	0	0	0	1	0	5	0	3	3	0
November,	2	0	0	0	0	0	0	0	3	0	2	1	0
December,	0	1	0	0	0	4	0	14	18	1	0	2	0
Year,	6	16	7	1	3	15	7	47	89	8	14	23	2
Difference from Average 1770-1896,	−23	?	+1	?	−1	−6	−3	−18	?	−7	?	?	?

	Earth Thermometers. Read Daily at 9 A.M.							
	Mean Temperature.				Variability of Temperature.			
	3 ins.	12 ins.	22 ins.	Air Temp. at 9 A.M.	3 ins.	12 ins.	22 ins.	Air Temp. at 9 A.M.
January,	35°·9	38°·7	39°·4	36°·5	1°·8	0°·6	0°·5	4°·2
February,	35·6	37·2	37·6	37·6	1·4	0·6	0·4	4·2
March,	38·4	40·0	39·6	40·5	2·1	0·9	0·6	3·9
April,	42·3	43·2	41·4	45·0	2·3	0·5	0·4	4·5
May,	48·2	48·1	46·8	48·0	1·7	0·8	0·4	3·2
June,	58·0	57·1	55·0	60·1	1·6	0·5	0·4	4·0
July,	59·5	58·4	56·8	61·8	1·4	0·6	0·4	3·6
August,	61·3	60·2	58·5	61·2	1·6	0·7	0·3	3·1
September,	51·3	55·2	55·1	53·3	2·2	0·4	0·3	3·8
October,	45·8	48·2	48·7	48·1	4·1	0·5	0·3	6·0
November,	44·0	46·0	45·7	47·3	1·3	0·7	0·3	4·4
December,	35·5	39·6	40·7	35·3	1·8	0·7	0·5	4·4
Year,	46·3	47·7	47·1	47·9	1·9	0·6	0·4	4·1

XXI. *Preliminary Note on the Development of* Cribrella oculata. By Arthur T. Masterman, M.A., D.Sc., *Lecturer in Zoology at the New School of Medicine, Edinburgh.* [Plate IX.]

(Read 21st March 1900.)

Cribrella oculata and *Asterias Mülleri* are two common star-fishes of our coasts which have demersal larvæ enclosed in a "brood-cavity" formed by the arms of the mother. The stages of the former have been figured externally to some extent by Sars many years ago. The development itself has some very peculiar features, which should prove full of interest to morphologists. The main points are these:—

1. The segmentation is at first total and unequal, closely resembling that of the frog, but later a free cell-formation occurs through the whole egg, and a solid morula is finally produced, with cells of equal size throughout.

2. Gastrulation appears in some cases to be effected normally, though it has been as yet impossible to connect the gastrulæ with either the morula on the one hand, or with the later larva on the other hand.

In other cases the hypoblast appears to be formed either by multipolar gastrulation, or by multipolar ingression of single cells.

3. The uniformly ciliated slightly oval larva, when hatched, shows an epiblast with a pit at the posterior end, which is either the ontogenetic or phyletic vestige of the blastopore, containing a mass of nuclei and cytoplasmic strands in which lies a hollow sphere of hypoblast, which is usually in contact with the blastoporic pit, and filled with the same material as surrounds it.

4. The mesoblast is formed from two rudiments. The first, or anterior, is constricted off from the front end of the hypoblast, and the second, posterior, is later constricted off from the hind end. The anterior divides almost entirely into left and right hydrocœle and preoral cœlom, and the posterior divides into left and right enterocœle.

Of these the preoral cœlom survives mainly as the axial sinus (as in *Asterina* and *Bipinnaria*), and the right hydrocœle disappears by differential growth. It is never completely separated from the anterior cœlom, and it is merely merged into the latter.

The left enterocœle gives rise mainly to the hypogastric cœlom (Goto), and the right enterocœle to the epigastric cœlom (Goto).

5. At the dorsal posterior border of the anterior cœlom, immediately above the archenteron, is constricted off a small vesicle, which soon becomes thin-walled, and closely resembles the preoral sac of *Balanoglossus*. Before separation from the preoral cœlom, it is carried over to the right, as in Fig. 4. It persists in the adult as a closed vesicle near the madreporite, and apparently has been described in *Asterina* by Macbride as a right hydrocœle. Bury describes the same organ in *Bipinnaria* and others (*cf.* Field) as a schizocœlic contractile vesicle.

6. The anterior end of the larva has three arms by which

it fixes itself, and development then proceeds spirally from the antero-ventral part to the postero-dorsal.

7. The perihæmal cavities arise very much as described by Macbride in *Asterina.*

8. Certain of the young star-fishes rotate their preoral lobe through 90° or so, in such a way that the water-vascular ring is then ventral if the larval plane be judged by the arms of the lobe, as described by Goto, but this does not appear to have the important significance attached to it by that author. There is no question that the left and right of the larva become the ventral and dorsal sides of the adult.

In giving these leading points, we may note that the two enterocœles arise in this species as in *Antedon,* and in this respect differ from all other Asteroidea. It follows that there is no difficulty in determining the subsequent fate of each. Again, the right hydrocœle appears to be present only as long as the plano-symmetry (bilateral) of the larva is maintained, whilst the preoral sac remains throughout life as a (? contractile) vesicle, which is evidently homologous with the pericardium of *Balanoglossus* and *Cephalodiscus,* so that an even closer comparison with these can be instituted. I hope to show that the much maligned vascular system of the star-fishes is really existent and comparable to that of Hemichorda.

Certain conclusions with regard to the general morphology of the Echinoderms can be merely stated here.

There appears to be evidence that the dipleurula stage (with two hydrocœles and a preoral sac and five pairs of tentacles) first took to the habit of lying on its right side, much after the manner of the Pleuronectids, and that in consequence of this the left side was hypertrophied at the expense of the right, the mouth moved to the left (upwards), and the five left tentacles tended to surround the mouth. *After this, and independently of it,* the animal further became attached by the preoral lobe, when the well-known movement through 180° of the principal organs, and the adoption of axial symmetry, resulted (as in *Antedon*). Only *after this* was effected did the Asteroids lose connection with

their stalk, and become free. The development of *Cribrella,* though, as in *Asterina,* apparently favouring Macbride's view, which would lead us to suppose the Crinoids and Asterids to be widely divergent, seems nevertheless to furnish some direct evidence to the contrary conclusion, and for reconciling the ontogeny of *Asterina* and *Antedon.* Lastly, there occur certain specimens which are enantiomorphs of the normal. The right hydrocœle forms the ambulacral system, and so on. When we consider that with the destruction of the preoral lobe all evidence of the peculiarity of these specimens is removed, one is led to believe that this may be of comparatively common occurrence in natural conditions, as in flounders.

Figs. 5 and 6 are meant to indicate that it is possible to draw as close a comparison between the demersal echinoderm larva and the young *Balanoglossus* as between the pelagic echinoderm larva and *Tornaria.*

Explanation of Figures.

Fig. 1. Coronal section through young larva, showing blastoporic pit and vesicular archenteron.

Fig. 2. Coronal section through later stage. The archenteron has given off at the front end a large anterior cœlom.

Fig. 3. Coronal section through rather later larva. The two hydrocœles are becoming constricted off from the rest of the anterior cœlom, which will form the preoral cœlom, contained in the preoral lobe. The posterior cœlom is arising from the hind end of mesenteron.

Fig. 4. Dorsal view of three-armed larva, seen as transparent object. The left and right enterocœles grow forwards ventrally and the left dorsally; not shown here, but seen in Fig. 6. The preoral sac is arising from preoral cœlom to right side of middle line.

Fig. 5. Diagram of young *Balanoglossus* (collar-pores omitted). Dorsal view.

Fig. 6. Diagram of late *Cribrella* larva, before fixation. The hydropore does not in reality perforate the ectoderm till later, but is in this position in *Asterina* and others. Dorsal view.

XXII. *Notes on a Collection of Mammalian and other Fragmentary Bones obtained from Smoo Cave, Durness, Sutherlandshire.* By DAVID HEPBURN, M.D., F.R.S.E., *Lecturer on Regional Anatomy, University of Edinburgh.*

(Read 18th April 1900.)

The material upon which the following observations have been made was found by the officials of Her Majesty's Geological Survey, and, by the kindness of Mr Peach, F.R.S., it was placed in my hands for examination and report.

The "find," consisting of numerous fragments of bones, along with a few shells, constituted part of a "kitchen midden" which had accumulated on the floor of Smoo Cave, Durness, Sutherlandshire.

With the geological characters of the cave and its surroundings I am not immediately concerned, although these might throw light upon the presence of certain of the bony remains.

The material, as submitted to me, consisted of two separate parcels, of which one had been collected by a private individual, while the other and larger package had been gathered by the Survey Collector, who made a careful distinction as regards the level at which different fragments were found, and classified them as from the "Upper Layer" and from the "Lower Layer." In the course of my observations, I shall continue to distinguish between the "Survey Collection" and the "Private Collection."

I. THE SURVEY COLLECTION.

A. *Upper Layer.*—In this portion of the "find" there were more than sixty fragments of mammalian bones, many of which were mere chips, whose specific identification was impossible. In addition, there were numerous bones of birds and fishes, as well as some shells, of which the majority were apparently oyster-shells.

Although the total number of mammalian fragments was large, yet only a few genera could be identified. Thus the

great majority of the fragments were remains of red-deer (*Cervus elaphus*), and indicated a considerable number of individuals, varying in age from animals whose full complement of teeth had not yet erupted, to those which were quite adult. Among the bones collected there were portions of jaws with teeth, part of the base of a skull, the humerus, scapula, radius, and ulna, metacarpal bones and phalanges of the fore-limb; os innominatum, tibia, os calcis and metatarsal bones, and phalanges of the hind-limb; as well as numerous ribs. In addition to the mere identification of these fragments, it is worthy of remark that one of the metatarsal bones presented some traces of tooth-markings, while a well-preserved os calcis of large size showed an incised depression about half an inch long upon its outer surface. Another os calcis, belonging to a smaller animal than that just referred to, presented many tooth scratches, and its tuberosity had quite clearly been gnawed away.

The sheep (*Ovis aries*) was represented by several distinctive fragments. Thus, part of a right mandible carrying two teeth, viz., a præ-molar and a molar, as also portions of the tibia, humerus, and ribs, could be identified. One other mammal was represented by a left tibia. Beyond stating that this animal was about the size of a mouse, it is impossible to be more precise.

None of the other fragments could be referred with certainty to any special mammal. A number of characteristic bird-bones were present. These were leg and wing bones of a bird not quite so large as an adult swan, and they might be those of a large goose. There were numerous fish-bones, and several shells.

B. *Lower Layer.*—In this portion there were over twenty fragments, of which only eight or nine could be accurately identified. Of these, again, there were seven which belonged to the red-deer, but not all of them to the same animal. A young lower jaw with a non-erupted molar tooth, and the shaft of a humerus minus its epiphyses, may have belonged to one animal. A single molar tooth, as also two fragments of an unidentified long bone, may possibly have been subjected to the action of fire. A præ-maxilla; part of a metatarsal bone; a

portion of a rib and the tyne of an antler completed the remains which could with certainty be referred to the red-deer. Of these, the metatarsal fragment presented characteristic tooth-markings, and a few similar indentations were found on the tyne and the shaft of the humerus. In this "find" there occurred the shaft of a single phalanx of a large Cetacean. The fragment was four inches in length. It presented tooth-marks, and had lost its articular ends along their epiphyseal planes. A number of rib fragments probably belonged to the red-deer, but some of them may have belonged to the sheep. Lastly, there was the left humerus of a bird. This bone was complete. It measured two and a quarter inches in length, but it was not sufficient for accurate determination.

II. The Private Collection (Mr Barnes).

In this portion of the collection there were no fewer than seventy-four fragments of mammalian bones, besides a considerable number of large fish-bones. The great majority of the mammalian bones were too fragmentary for accurate identification, but it appears quite fair to assume that the uncertain specimens may be referred to one or other of the mammals indicated by the twenty fragments whose determination was possible. The red-deer and the sheep contributed the greater number of the specimens, but several fragments were distinctive of the seal, probably *Phoca vitulina*, while the femora and tibia of man were represented by four fragments.

The human femora belonged to one individual, but in their very dilapidated condition a complete examination was impossible. Enough remained to show that they represented an adult person, probably a male. One of the bones was minus its head and trochanters, and its internal condyle was abraded away, thereby making a complete series of measurements impossible. Only the upper third of the shaft of the other femur, the right one, remained, and at both ends this bone was much reduced by apparently having been gnawed. The representation of the right tibia merely consisted of a

flat splinter, showing part of the popliteal or soleal ridge, with small portions of the adjoining popliteal and flexor surfaces of the shaft. From the better of the two, viz., the left, I was able to obtain measurements of the shaft, and these are of considerable interest. In the sub-trochanteric region the antero-posterior diameter was 28 mm. and the transverse diameter 34 mm., thereby giving a PLATYMERIC Index of 82·3. In the region of the linea aspera the antero-posterior diameter was 32 mm. and the transverse diameter 27 mm., giving a PILASTRIC Index of 108·5. In the popliteal section of the shaft, at a level 4 cm. above the articular margin of the external condyle, the antero-posterior diameter was 33 mm. and the transverse diameter 47 mm., giving a POPLITEAL Index of 70·2. The popliteal diameter "mp" was 33 mm., and "mn" was 34 mm., thereby indicating that there was no tendency towards convexity of the popliteal surface of the shaft.

Even in their imperfect state these figures do not indicate anything at all remarkable. In any of the particulars recorded, this bone might quite well be a modern British femur. It presents marked differences from the femora of the Oban Caves, described by Sir Wm. Turner,[1] as well as from a series of femora obtained near an old Roman wall at Leicester, the details of which I recorded some time ago.[2] The resemblances to a modern femur are so close, that I should like to know whether the relation of the human remains to the "kitchen midden" corresponded with that of the other bones in the collection.

The red-deer was represented by several bones of much larger dimensions than in the Survey Collection, such as lower jaw, ulna, metacarpus and metatarsus, a præ-maxilla, and a nasal bone. One of the metacarpals was much indented by tooth-marks, and had also been split open by teeth.

The contributions from the sheep were a portion of a mandible containing three molar teeth, a fragmentary

[1] Turner, "On Human and Animal Remains found in Caves at Oban," *Proc. Soc. Antiq. Scot.*, 1895.

[2] Hepburn, *Jour. Anat. and Phys.*, vol. xxxi. pp. 116-156.

scapula, radius, atlas, and ischium. The last four specimens were from a very young animal. A Cetacean was represented by a single phalanx, evidently fragmentary, and only one and a quarter inch in length. This phalanx belongs to near the extremity of a digit.

From the seal there were part of the right mandible, containing two typical teeth, and also the right half of the promontory of the sacrum.

Among the remaining fragments there were many portions of the shafts of such bones as the humerus and femur, with portions of ribs, which might quite well have belonged to the deer and sheep, so far as their size was concerned. Some of them were tooth-marked, and one rib fragment had been cut with a powerful, clean-cutting, sharp-edged weapon.

The fish-bones in the collection were from the head, jaws, vertebræ, and fins, etc., and they were all of considerable size. I have not attempted to identify these.

So far as the identification and examination of the various fragments is concerned, they do not suggest any great antiquity for the ancient accumulators of the "midden," nor any special climatic conditions under which they lived. At the same time, they provide evidence of a varied diet on the part of the inhabitants of the cave, a variety which took nothing amiss, and which, with the true instinct of the pot-hunter, regarded the Cetacean and the red-deer, the sheep and the seal, as welcome interludes in the monotony of a diet of fish and oysters.

The presence of the dog as the companion and assistant of this early hunter is suggested by the gnawed condition of many of the bones, but of the animal itself no skeletal remains were discoverable among the broken fragments which have been collected. If the human remains which have been gathered really correspond in age with the other parts of the collection, then their form of interment, to judge from the gnawed condition of one of the femora, must have been hasty and indifferent.

XXIII. *The First Foundation of the Lung of Ceratodus.* (Preliminary Notice.) By Gregg Wilson, Ph.D., D.Sc.

(Read 21st March 1900.)

Ceratodus, the lung-fish of Queensland, is interesting as being one of the few modern fishes in which lung-breathing supplements the ordinary respiration by gills. It has one lung, in the position of the swim-bladder of ordinary fishes; while the closely-related *Protopterus* of Africa, and *Lepidosiren* of South America, have each got two lungs. These three forms (the Dipnoi) seem to constitute a connecting link between Pisces and Amphibia, yet the relationship is not clear, and some zoologists prefer to connect the amphibians with such primitive Ganoid forms as *Polypterus*. The real affinities will only be fully apparent after a study of the embryology of the different groups has been made, and as yet little has been done in that direction, either with Dipnoans or with the primitive Ganoids. Semon's splendid *Ceratodus* material has yielded results as to early stages and the development of fins, teeth, etc., but there is still much to be done in the study of the Dipnoi.

During a recent visit to Australia I was fortunate enough to get a series of eggs of *Ceratodus*, and developmental stages up to three months after hatching; and I am now working up this material, with a view to helping in the determination of the affinities of the Dipnoi.

One of the first organs to attract my attention was the lung of *Ceratodus*. Most zoologists believe that the lungs of amphibians and higher vertebrates are homologous with the swim-bladder of fishes, yet no one has explained why the former arise as a ventral outgrowth from the gut, while the latter is dorsal in its origin; no one has proved a change of position in the foundation of either structure. The only thing to reconcile us to the proposed homology is the fact that in certain fishes the swim-bladder is not connected in the adult with the dorsal side of the gut, but with the lateral or ventral wall; in *Erythrinus* it shows a lateral connection, while in *Polypterus* and *Calamoichthys* the opening is ventral.

In the Dipnoi the lungs are connected mid-ventrally with the gut in *Lepidosiren* and *Protopterus*, ventro-laterally in the case of *Ceratodus*. But in none of these has the development been investigated. It seemed important to me to see if in the group supposed to connect fish and amphibian there was anything to connect the swim-bladder of the one with the lung of the other. The answer is in the negative. The lung of *Ceratodus* arises like the lung of amphibians, so that the resemblance of Dipnoi to Amphibia is emphasised, and their remoteness from the Teleostomi.

In a young *Ceratodus* of about 14 mm. in length, and labelled "two months after hatching," I found a very early stage in the development of the lung. But in smaller specimens of less age I have distinctly later stages in the growth of the lung, so stress cannot be laid on size and age.

In my first stage, the foundation is only about $\frac{1}{100}$ mm. in length. It consists of a slight ventral pit or depression in the floor of the pharynx about the same level as the first pronephric nephrostome, and just posterior to the heart. It is quite median in position, and so differs from the communication between lung and gut in the adult. (See Fig. 1.)

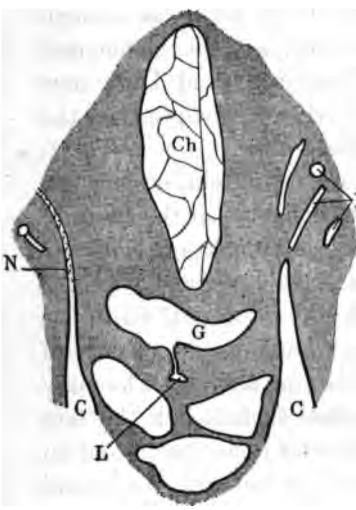


FIG. 1. C = cœlom ; Ch. = notochord ; G = gut ; L = foundation of lung ; N = pronephric nephrostome ; P = pronephros.

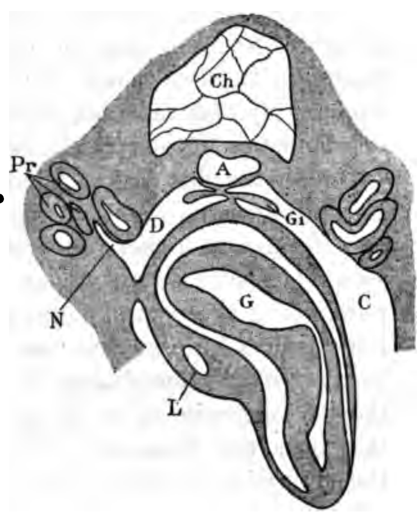


FIG. 2. A = aorta ; D = diverticulum of cœlom ; Gl. = glomerulus ; other letters as in Fig. 1.

A second stage is found in a specimen of three weeks, and about 13 mm. in length. It shows the same pit in the mid-ventral line of the pharynx, but the depression is deeper, passes a little towards the posterior, and bulges somewhat below the gut and at its side. The gut, which runs straight back to the point of communication with the foundation of the lung, here makes a rather sudden bend, so that the slight backward prolongation of the tubular foundation (seen in some fifteen sections, each about 10 μ thick) comes to lie at the side of the gut, near its dorsal surface. (See Fig. 2.)

A third stage is seen in a second specimen of two months and 15 mm. in length. In this the foundation of the lung is still in communication with the mid-ventral line of the gut (Fig. 3). It spreads out below the gut, which it almost equals in breadth, and it gradually comes to lie, first, laterally to it, and at its posterior end dorsally. In this specimen the whole foundation extends to about 0·8 mm.

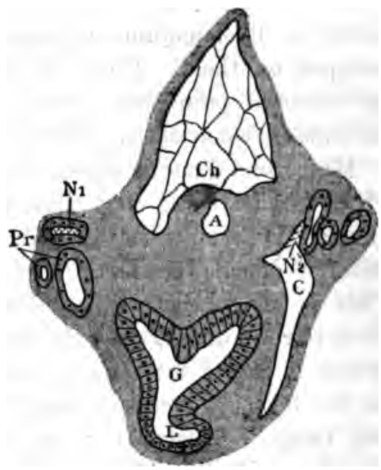


FIG. 3. Letters as in previous figures.

XXIV. *Embryonic Excretory Organs of Ceratodus.* (Preliminary Notice.) By GREGG WILSON, Ph.D., D.Sc.

(Read 21st March 1900.)

The fore-kidney, or pronephros of *Ceratodus,* is distinctly of the type found in Amphibia, and quite unlike what is found in the Teleostomi. In the latter group there are pronephric chambers, developed as diverticula of the pronephric tubules, and in connection with these chambers the "glomeruli" appear, projecting into the cavities. In Amphibia, on the other hand, the "pronephric chamber" is

originally part of the cœlom, into which the tubules open and the glomeruli project. The pronephros of *Ceratodus* agrees with amphibians and differs from bony fishes and Ganoids in these respects.

My earliest stage shows two tubules on each side, with nephrostomes opening freely into the cœlom. Between the nephrostomes, on either side of the mesentery, there is a lobulated fold, or glomerulus, hanging into the body-cavity. The tubules communicate externally with the segmental duct.

Later stages show the same tubules greatly coiled, but with no diverticulum or internal pronephric chamber developed on them. There is, however (as in amphibians), an external pronephric chamber formed on each side by secondary fusion of the gut with the body-wall.

My second stage is shown in a specimen three weeks old. Here, in the region immediately anterior to the pronephros, the gut is fused with the body-wall, so as to form a slight anterior dorsal diverticulum of the cœlom on either side. This is most distinct opposite the anterior end of the pronephros, and ends exactly opposite the first nephrostome, where it passes into the general body-cavity. (See Fig. 2 in the text of preceding paper, on the "First Foundation of the Lung of *Ceratodus*"; one side of the figure shows the chamber still complete, just where the first nephrostome is met; the other side shows the relations of parts slightly farther back.)

A later stage shows partial obliteration of the pronephric chambers; but these persist far enough forward to receive the nephrostomes.

Still later stages show further obliteration of the chambers anteriorly and a closure of the anterior nephrostomes. (See Fig. 3 in the text of the preceding paper; on one side the second nephrostome still opens into a reduced diverticulum of the cœlom; on the other side the first nephrostome is seen to be quite closed up by the secondary connection between the gut and the body-wall.)

After this stage the pronephros appears in a degenerating condition.

The mesonephros is of the usual type. It arises as curved bands of cells in the mesoblast. In each of these a lumen appears, and the inner end of this expands (Bowman's Capsule), while the tubule becomes long and convoluted, and opens at one end into the body-cavity, while the other end connects with the segmental duct.

XXV. *Simpler Methods in Crystallography.* Part I. Stereograms. By J. G. GOODCHILD, H.M. Geol. Survey, F.G.S., F.Z.S. [Plates X., XI., XII.]

(Read 18th April 1900.)

1. In the universities and other educational institutions, where much attention is devoted to the mathematical sciences, there may be said to be often a need for subjects of a sufficiently varied character to which these mathematical studies can be practically applied. The higher branches of physics furnish ample scope for such work in one direction, while in another the subject of Astronomy affords excellent opportunities for mathematical work of a somewhat different kind. For the same reason (though occasionally for the sake of the subject itself) a few students are now and then induced to apply their mathematical knowledge to the working out of problems in Crystallography. It results chiefly from this cause, that most of the treatises on that branch of science have been penned by those who have approached the subject from a purely mathematical starting-point. In consequence of this (which is, perhaps, almost unavoidable under the circumstances), Crystallography has usually been treated in such a manner that those workers who do not happen to possess the special knowledge necessary for the right understanding of these treatises, find themselves debarred at the very outset from doing any practical work in this really interesting branch of science.

2. Several years' practical experience in the determination of crystalline forms, and in the clinographic and other delineations of the actual crystals so determined, has fully confirmed a view that I have long held, that much useful

work can be done in Crystallography by means of simpler methods than have usually been employed. I therefore propose in this and some succeeding papers to describe my own mode of procedure, in language as simple as the nature of the subject will admit, under the firm conviction that, if these methods are mastered and followed, they will enable others to do much practical work in Crystallography of a far higher order than those who are accustomed to only purely mathematical methods may at first be induced to believe.

3. One of the first needs in practical determinative work in Crystallography is a thoroughly good set of maps, and a full knowledge of both the principles of their construction and of their capabilities. Provided with these essential requisites, with one or two good platyscopic lenses (Browning's), with an ability to estimate both the relative lengths and the directions of straight lines, and with the faculty of delineating those lengths and directions correctly by freehand drawing, the student of Crystallography may do a large amount of good work of a practical nature without having to use the goniometer, except in some few exceptional cases, and without having to perform more than a few computations that are of any other than a very simple nature.

4. The principles upon which crystallographic maps are constructed can be best comprehended by means of some fair-sized actual crystal, say one of Barytes. This crystal is to be placed at the centre of a hemispherical glass shade, and then we have to imagine that lines are drawn from the centre of the crystal perpendicular to its faces, and produced until these lines touch the glass. There is not much practical difficulty in doing this with an approach to accuracy sufficiently close for the purpose in view. The point where these lines would touch the surface can easily be marked by a dot of colour with the point of a fine brush. These points represent the POLES of the faces in question.

5. If there happen to be several faces present on the crystal under examination, it will soon be evident that the poles of these faces are arranged in such a manner that three or more than three are obviously in the same line. These

lines will be referred to as ZONES. Furthermore, it will soon be evident that the poles of each zone are perpendicular to one line, which will be referred to as the ZONE AXIS. It will also be obvious, in the case of Barytes, that each pole passes through a pair of faces, front and back, right and left, above and below, as the case may be; and that several of these pairs of faces are obviously symmetrical each to the other.

6. Some further aid in understanding the geometry of crystals, and the projection of the poles of the commoner forms, is to make a set of crystal models from nets such as Jordan's (Murby & Co.), and to place one simple form after another, all with similar orientation, in the place of the crystal, choosing the Orthorhombic system as being the most suitable for the purpose. By this means we can combine into one projection the whole of the forms represented in the series.

7. It is as well at first to turn the crystal about in several directions within the glass shade, and to draw in the poles and the various zones which include those poles, until the broader features are quite clear. When this stage is reached, the zones and poles may advantageously be studied in more detail with the aid of any good table of indices, such as are to be got from Dana.

8. The next step is to do the work somewhat more exactly by means of a fair-sized ball of soft wood, or even an india-rubber ball: the wooden ball is better for some reasons. Now, instead of the ink dots on the glass shade for the poles, insert small pins, each pointing as accurately as possible to the centre of the ball. Also pencil in the zones connecting them as straight as possible by hand. Note that these zones all form GREAT CIRCLES on the sphere—that is to say, that they all have a common centre with the sphere itself. It will not be difficult to put on the poles of a few other forms than one is likely to meet with on any single crystal, and in order to do this, some temporary departure must be made from the plan adopted in this paper, and we must, for once, have recourse to angular measurements. First, two opposite poles must be chosen to represent the front-and-back axis of the crystal, and we mark these (a), and in like manner the

right-and-left axis is to be marked at both ends (*b*), and the up-and-down axis is to be signed at both ends (*c*).

9. If the diameter of the ball is about four inches, that is a useful size for experimental work. We shall now need some means for drawing zones on the ball from point to point with some approach to accuracy. To do this I use two strips of clock-spring about eight inches in length, and connected side by side by two small strips of brass soldered across the ends, a sufficient space being left between the steel strips to admit a fine needle. If this is bent around any part of the sphere over which zones have to be drawn, it is easy to mark by a needle point a position anywhere intermediate between two other points and in the same line with them. Furthermore, it will not be found difficult to mark on this little instrument the degrees of a quadrant of a circle, so that when it is folded over the sphere in any direction, the angular distance of any one point from another may be laid down with ease, and quite near enough for the work at this stage. And if these points so determined are marked with small pins pushed into the ball, the morphology of the crystal will gradually come more and more clearly into view.

10. It is well at this stage to refer to the several poles by the letters or SYMBOLS used in the work which happens to be chosen. The INDICES which those symbols denote will be dealt with further on.

11. By this concrete method a large amount of real knowledge can be readily and easily acquired, and can be stored up in a form which (when only a small number of species is under observation) is extremely useful in many ways, some of which have not yet been referred to. I find, in practice, that hollow india-rubber balls answer, after some proficiency has been obtained, almost as well as the wooden balls. It may be mentioned here, as an illustration of the use to which these wooden balls, pinned out into zones, may be put, that they serve to indicate the direction of the intersection edge between any two faces. All that is needed is to describe on the ball, around each of the poles as centres, two circles. Their intersections on opposite sides give two points through which the required line is to be drawn. In arranging the

large collection of Scottish Minerals in the Edinburgh Museum of Science and Art, I have set out the poles of several species of minerals on four-inch wooden balls by means of a more complex instrument for laying down spherical triangles than the simple device here described. The Goniograph referred to, which was made by the Museum staff to my design, is exhibited amongst the scientific instruments in the Edinburgh Museum of Science and Art.

12. But it must be obvious that where much crystallographic work of a varied nature has to be done, the wooden balls, useful as they are, sometimes prove a little inconvenient to carry about, just as a geographer or a seafaring man would find it inconvenient to carry about a terrestrial globe of any useful size. We are thus led to seek for some suitable chart or map which shall represent in one plane all the forms represented on the solid.

13. Here a difficulty is encountered, because it is not possible by any means to transfer the poles and zones from a spherical surface to a plane one, without a certain amount of distortion so far as area is concerned. But it is well to remember in this connection that in Crystallography we are concerned only with DIRECTIONS and not with magnitudes, so that this apparent defect is really of no consequence.

14. There are several methods of representing crystallographic zones and poles on a plane surface—each method possessing some defect, and at the same time presenting advantages of its own. An excellent method, much used in former times on the Continent, is Quenstedt's Linear Projection, of which a good account is given in several books on mineralogy, notably in Groth's *Physicalische Crystallographie*, and in Bauermann's Mineralogy. It is also described in Dana's Manual. As these are easily seen, and as the method of projection offers no special difficulty, it need not be further noticed here, especially as it has no very evident connection with the subject of this paper.

15. Another method of projection which is very useful in certain cases, is that which is usually called the Gnomonic Projection. For the maps made upon this principle, I have

coined the word Gnomonogram. The methods of construction of gnomonograms lead by easy gradations up to the more complex methods involved in making Stereograms, and therefore its consideration may profitably be noticed here in some detail.

16. To begin, we will employ concrete methods as far as possible, as before. Instead of a small, simple crystal, we will now take a series of crystal models, including all the simpler forms, such as can be got by using Jordan's Crystal Nets already referred to. We may as well begin with the Orthorhombic System, as before. It is as well to have each crystal model mounted on some kind of stand—a cork coated on the top with seccotine does well for the purpose. Now mark the position of the three axes, which can be done by small pins stuck into the models. It is advisable also to employ some kind of symbol for each kind of face, using, preferably, the symbols accepted by Dana.

17. We may now place each simple form in succession at the centre of a hemispherical dome of glass as before, project its poles on to the glass, marking those of each form with its distinctive letter or symbol (not with the *indices* at present), and doing this with the whole series, as before advised. Then all the various zones connecting any three of these along a great circle can be marked in upon the hemisphere.

18. When this has been completed, the hemisphere is to be fixed by any suitable means, and then a large and flat sheet of glass is fixed so as to lean against the hemisphere, which it may touch at *any* point, but preferably at the pole of the UNIT PYRAMID of Miller's notation (111). If, now, the eye be moved to various positions in succession, so that it and a point on the glass hemisphere are in a line with the centre of the hemisphere (which henceforth will be denoted by O), there will be found no difficulty in marking the places on the sheet of glass—in other words, in projecting the points in question from a spherical surface to a plane one. It will soon be evident that the zones (which mark GREAT CIRCLES on the sphere) project on the flat surface into straight lines, so that the whole of the projection now under con-

sideration consists of points and of straight lines connecting those points with others.

19. It is advisable now to copy the lines on to paper, and then to repeat the experiment with crystal sets belonging to several different systems (avoiding the monosymmetric and anorthic for the present). Much is learnt by the process, and a good solid foundation is laid for the work that is to follow. When this has been done, it will be clear that the gnomonogram represents an eighth of the surface of the sphere in the Cubic, Tetragonal, and Orthorhombic systems, and a twelfth in the case of the Rhombohedral. There is no practical disadvantage in this which is not quite counterbalanced by many advantageous features which this mode of projection presents. Also it is well to notice that in the case of the gnomonogram, it is the poles and zones on the *convex* surface of the sphere which are projected, and that on the side next the observer's eye.

20. As soon as the worker feels that the principle of construction has been made quite clear by the method of procedure described, this rough and inexact mode of work may be exchanged for geometrical methods, by which almost any required degree of precision may be attained.

21. At this stage the wooden ball marked with all the leading poles and their zones, may well be kept constantly before the eye. Its utility at the present stage is increased if rather large pins are fixed in the position of the principal axes (a, b, c). If we turn the ball about so as to view it in a variety of directions, it will be quite clear that each point on its surface is equidistant from o, the centre. Bearing this in mind, let us lay down a circle to represent the boundaries of the sphere, choosing some radius easily divided into decimal parts to at least three places. A decimal scale for this purpose can easily be constructed on a large sheet of good drawing-paper by the following method:—Fix a metre scale some distance to the right hand of the drawing-board upon which the paper is fixed, and parallel to one of its edges, also a fine steel needle at about a decimetre to the left, and at a point parallel with the extremity of the scale. Then with a good steel straight-edge moving against the needle on the one

side, and the various divisions of the metre scale on the other, draw fine lines in carmine ink for the decimetre divisions, in blue for the centimetres, and in Indian ink for the millimetres, continuing these least subdivisions towards the needle only as far as they remain clearly separate. From this scale, which we shall use under the name of the DECIMAL SCALE, a line of any length likely to be needed can be divided accurately into any required number of decimal parts to three places—the unit being the distance across the scale measured at right angles to the base line.

22. Choosing from this scale a radius equal to five centimetres, we carefully draw in a circle of a decimetre in diameter, across which are to be drawn two diameters at right angles to each other, which divide the circle up into four equal quadrants. These may be lettered with Roman numerals I., II., III., IV., taking the first figure in the bottom left hand quadrant, and the others in order counter-clockwise. The circle in future will be referred to as the PRIMITIVE, or the CIRCLE OF PROJECTION, because it represents on paper the sphere of projection formerly used. Its centre is to be signed O, which stands for ORIGIN. From O produce the cross diameters beyond the circle, and conceive of these lines as indicating simply *directions*. The right and left direction will be referred to as OX, and the direction at right angles to that as OZ, in both cases regardless of the *length* of the lines in question. (See Fig. 1.)

23. Suppose now that we have an orthorhombic crystal to project, and that we take Barytes as a fairly easy one to deal with. The first point to notice in this is that the crystal molecules in this species are arranged in such a manner that the unit form of the resultant crystal builds a solid in which the three axes are of markedly unequal length. Let us assume for working purposes that the right and left axis OX represents unity in the proportions of the crystal as well as the radius of the circle of projection. If we turn to "Dana" we find that, relatively to this unit, the front and back axis (a) is less than unity, and measures ·8452, while the vertical axis (c) is greater than unity, and measures 1·31359. We take the first three places of decimals

as being as close as an ordinary geometrical draughtsman can practically work; and assuming that quadrant IV. in the circle of projection represents the sphere as seen from its side at *b*, we measure off on OX a distance ·845, and on OZ we set off 1·313. With a fine pointed pencil and a straight-edge these two points are joined, and the line prolonged both ways across the circumference of the circle. Then from the points where this line cuts the circle, with any convenient radius, two intersecting arcs are described, and a line is then drawn from the point of intersection to O. Next, at right angles to this line, draw both ways a line touching the circle of projection and cutting OZ, OX. Sign these points by any arbitrary symbol, say the one on OX with a capital A, and the one on OZ with a capital C.

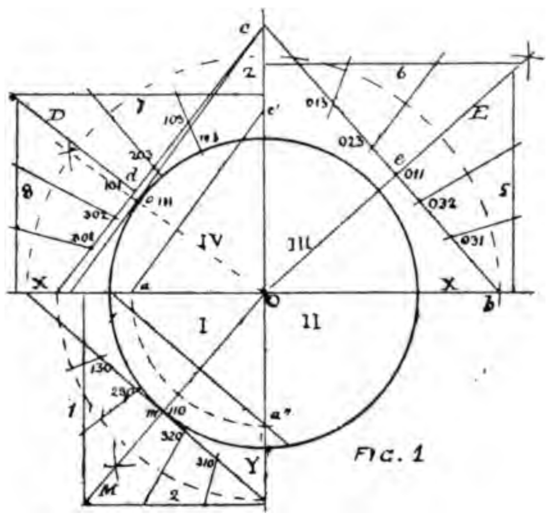


FIG. 1

24. If the ball with the sheet of glass tilted against it be referred to, it will be seen that C corresponds to the point on the sheet of glass where the vertical axis touches the glass, and that A represents the nearest point where the foot of the sheet of glass approaches the ball along that line. Right and left of the point on the glass corresponding to A, it will be seen that the glass is farther away still. We now require, therefore, to determine the position of these points more exactly. With this end in view, set off a quadrant of a

circle from O on a centre, and radius OA in connection with quadrant I. Now, we have to conceive that we are looking down upon the sphere from above; but as all points on its surface are equidistant from its centre, the point of view is quite immaterial. We require to find a line which will touch OA in the quadrant I., and be parallel to a line touching the front axis O*a* on the one side and the right axis O*b* on the other. *b* being understood to be unity (or the radius of the circle of projection), we have only to join a point at ·8452 of the one axis in II. with the unit length on the other. As before, produce these lines to cut the circle of projection, draw intersecting arcs from the points where they do so, and rule a line through them to the O in one direction, and to any arbitrarily chosen distance in the other. At right angles to this draw a line touching the outer arc of the circle in I., and produce it both ways until it cuts OX, OY. The line so obtained gives the length of the base of the gnomonogram of this species to the radius and the point of contact chosen. Where it cuts the perpendicular in I. is the important crystallographic pole *m* (110); where it cuts OY is the position of *b* (010), and where it cuts OX is the position of *a* (100). Measure on OX, in IV., the distance O*a*, and draw *ac*, and erect a perpendicular to that line so that it passes through O. Sign the point where this line cuts *ac* with a *d* (101). Next, from O with a radius O*b* describe an arc of a circle cutting OX on the right in III. Join this point with *c*, and erect a perpendicular upon it, passing outward from O, as in the other quadrants, signing the point where it cuts *bc* with *e* (011).

25. With these data on the working map, we are prepared to set out the chief lines and poles on the required gnomonogram. On a separate sheet of paper, not less than imperial size, draw a line about five centimetres from the base, and on the right half of this line, at about three decimetres from the end, mark a fine dot and sign it *m* (110). From this point measure to the right *mb*, taken from the working map, and to the left *ma*, signing *a* (100) and *b* (010). From *a* as a centre with radius *ac*, and from *b* with a radius *bc*, describe intersecting arcs, and mark the point thus determined *c* (001). From *c* draw a line to *m*: if the work has been properly done,

this line should be perpendicular to *ab* at *m*. Next, from *ac* on the working map, take off the distance *ad* or *cd*, and set it out with its symbol *d* (101) on *ac*. In like manner set off *be* or *ce* on *bc*, and sign the point *e* (011). Draw lines from *m* through *d* and *e*: also from *b* through *d* and *a* through *e*: produce them indefinitely. The point where these letters cross *mc* should be that of their common intersection. It marks the point of contact of the plane of projection with the sphere of projection, and also the pole of *o* (111), or that pyramid whose face touches each of the three axes at their normal length.

26. It may be remarked here that the points *a*, *b*, *c*, *d*, *e*, *m*, *o*, whose positions are thus determined, are the seven cardinal poles or primary points, marking the poles of the unit forms in all these projections and in all systems. As that is so, it is desirable to employ for them a uniform set of symbols, which has not yet been consistently done by any writer, but will be done so here.

27. In determining the position of the poles to the secondary faces on a gnomonogram, it is quite possible to work by a system of intersecting lines drawn from various points whose position can be laid down in succession on the drawing itself. As the principle upon which this method of working is one of great importance in practical Crystallography, it may be referred to in some detail, even though the position of any pole may be more easily determined by methods to be presently described. The principle referred to depends upon the fact, already stated here more than once, that the various poles in Crystallography lie in zones whose axes bear a very definite geometrical relationship to each other, and this relationship is of a proportional nature rather than of one connected with the kind of angular measurement of the kind employed for other purposes. If we can determine the position of a few of these cardinal points, lines drawn from them through certain other positions will at once determine the positions of sets of poles belonging to other zones, and the process may be continued from point to point until each pole on the projection is connected with every other pole with which it lies in zone.

28. It is necessary at this point to explain more fully what is meant by the INDEX in Crystallography. Taking 111, already referred to as an illustration, that index informs us that the plane represented by that is one which touches all three axes, *a*, *b*, *c*, at their full length. 101, means that the plane it represents touches the first axis at its full length, does not touch the second, that is to say, the plane is parallel to it, and touches the third at full length. It is customary to take the front-and-back axis *a* first, the right-and-left axis *b* second, and the up-and-down axis *c* as the third figure. (035) means that the plane referred to is parallel to *a*, cuts *b* at ONE-THIRD of its length measured from O, and cuts *c* at ONE-FIFTH from the same point. (749) means that the plane is one which cuts (or intercepts) *a* at ONE-SEVENTH from O, and the other two at one-fourth and one-ninth respectively. These fractions might, of course, be written as $\frac{1}{7}$, $\frac{1}{4}$, $\frac{1}{9}$; but if the fractions are *always so arranged that the numerator is* 1, it is obvious that it can be understood, and we may write the denominator simply in place of the fraction. This mode of expressing the relationships of the faces of a crystal by its INTERCEPTS, which in no case exceed unity, was invented by Whewell and brought into use by Miller, and is now almost universally used in place of each of the many cumbrous notations which have been from time to time invented and used.

29. In all cases in which the index consists of more than one fractional length, we may simplify the work by the method based upon the following:—Suppose the index is 305. This signifies that the plane whose inclination is so expressed cuts *a* at one-third from O, is parallel to *b*, and cuts *c* at one-fifth from *o*. Draw a right angle on a separate piece of paper, and mark the angle O. Measure off one-fifth from O along one axis and one-third from O along the other, and join the two points by a straight line. If the lines were short to begin with, we may find the fractional lengths inconveniently small for practical work. Now, as we are concerned with directions and not with magnitudes in this case, it matters not how far the plane in question is from O provided its *direction* remains the same. So we may multiply

each of the two fractions by any number we please. We might, for example, take *a* at full length (*i.e.*, three-thirds), and *b* at three-fifths, and still get the same result as before. In practice this is what is done. Indeed, the older writers on Crystallography actually expressed the direction of the planes by a method much the same; and it is only because the Whewell-Miller system is so much neater, and more useful in other ways, that the intercepts are expressed by fractions in which the numerator is simple unity—to be understood, and therefore not to be written.

30. The first step is to join *ed*, and produce the line (in this case towards the left hand) until it cuts the continuation of the line upon which *amb* stand. If the work has been done well, the point of intersection thus marked will be the projection of the pole of *m*, which lies in the quadrant of the sphere of projection to the left of that represented by the gnomonogram. It is well to sign this pole M. It forms a radiant point for all the poles in zone with corresponding position on *a* and *b*, as, for example, 102, 012; 201, 021; 506, 056; 605, 065, and so on; so that lines drawn from M through either of each pair gives the position of the other, as well as of any other pole in zone with them.

31. Next join M*c*, and join also *bd*, and produce the line to meet M*c*; the point so determined is the pole of the unit octahedron (answering to *o*) in the same quadrant as M. Join also *am*, and produce the line until it meets the prolongation of *ca*; the point of intersection is *d* in the quadrant below, and is again a useful radiant point for many zones of importance. Another valuable radiant point is found by joining *dm*, and prolonging the line below until that line, the gnomonogram, cuts the continuation of *cb*; the point so determined is the *e* of the quadrant below. We might usefully refer to these last two points *d* and *e* by italic capitals, *D* and *E* respectively. In practice, having laid down the exact position of *D* and *E*, fine needles are fixed at either of them, say at *D* first, and from this as a centre draw lines through any pole determined on *ab* to cut *cb*, on which the corresponding pole will thus be found. Thus a line from *D* through 310 marks on *bc* the position of 013, and of all the poles in that

zone; so from 520 gives 025, from 230 gives 032, from 150 gives 051, and so on, the indices on *bc* being simply those on *ab* in reverse order. It will be also evident, as the work becomes more familiar, that the intervening indices follow each other along such zones in a definite order of change: thus in the zone 110-011 they run in this order:—121, 132, 143, 154, 165, 176, 187, 198, there being, as is seen, an addition to the initial index of the final term of the series.

32. In like manner, drawing lines from E through any given point on *ab*—say from *m* 110, the line cuts *ac* at the corresponding position, in this case at 101—the second and third figures of the index changing places, and the intermediate indices changing by the continued addition of the final term of the series, as in the case just described. Thus from 110 to 101 we have first 211, 312, 413, 514, 615, and so on. Or, if the line cuts *mb* at, say, 120, the terminal index on *ac* is, by the rule, 102. The continual addition of this latter gives us $120 + 102 = 222$ ($= 111$), 324, 426 ($= 123$), 528, 6.2.10 (which is the same as 315), 417, 519, and so on. It is useful also to know that along the zone *ao* lines radiating from E give indices whose second and third figures are alike, and are the sum of the indices on *ab-bc*. Thus the line from E through 210 to 201 cuts *ao* at 411, that from E through 520 to 502 gives on *oa* 10.2.2 ($= 511$), so from 230 to 203 gives 433.

33. Again, lines from D cutting *ob* give indices whose first and third figures are alike, and are the sum of those on *ab* added to those on *cb*. Thus:—D through 110 to 011 gives on *ob* 121, through 230 to 032 gives 262 ($= 131$), 130 to 031 gives on *ob* 161, and so on. The same is true of all the indices along each zone; so that if we have before us any three in the same zone, the fourth and succeeding indices can at once be stated. This property forms the basis of an important law in Crystallography.

34. The poles on *mc*, which are usually of much importance in Crystallography, have the first and second figures alike, and are less than the third on *oc*, while those on *om* are greater than the third. They are always the sum of 010 (*b*) with the indices on *ac*; or the sum of 100 (*a*) with the

indices on *bc*—in both cases along lines from *b* or *a*, as the case may be.

35. A few examples worked out on a very large scale gnomonogram will teach other principles of the same kind, which, although of considerable importance in practical work, as well as in their purely mathematical aspect, need not be considered in further detail here. I may, however, remark that I have constructed a large scale gnomonogram on a sphere of projection of 50 centimetres radius, upon which a large number of poles have been laid down by an extension of the methods described. Such a map is of great practical use, as showing at a glance what three poles lie in the same zone, and in giving at once the position of the zone axis belonging to those poles.

36. Returning now to a simpler case, such as that presented by Barytes. We have already seen how the seven primary poles are determined; and we have next to consider how those of secondary position may be determined without going through what would often prove to be a somewhat tedious process if we were restricted to the mode just described. For this purpose more construction lines have to be added to the working map. We wish, for example, to mark the exact positions of 301, 103, 607, 908. The middle index being zero, they will all lie upon *ac*. Therefore in quadrant IV. produce O*d* to any convenient length, sign it D, and erect a perpendicular upon OZ to meet the line from O*d*, and figure it 7. Do the like from OX, and figure the line 8. All the indices in which the first is the greatest figure will be upon *da*, and those in which it is least upon *dc*. To determine 301, therefore, measure one-third of 8 from its termination at OX, and draw a line from that point to O. The distance of this point from *a* along *ac* is the length required, which is transferred to the gnomonogram. For 103, in like manner, measure one-third of 7 from O*c*, and proceed as before. It is also the case that 607 is at a distance of one-seventh of 7 measured from D, and 706 may be measured one-sixth from D on 8; all lines being transferred to *ac* by radii from O as before.

37. In like manner, if we have to determine the position

of 056, 065, 032, 023, we see that the zone upon which they all occur is parallel to *a* and is not parallel to *c*, whence it follows that it must coincide with *cb*. We proceed, as in last case, producing O*e*, signing it E, and erect a perpendicular to OZ to touch E, figuring the line 6. Also a perpendicular to OX is raised also to touch E, and the line figured 5. All indices in which the second figure is greater than the third are to be measured on 5, and those in which it is less upon 6. Five-sixths is measured from *c*, or one-sixth from E, and the distance projected on to *cb* by a line radial to O as before. For 065 we reverse the fraction as before, and measure five-sixths on 5 from OX, or one-sixth on 5 from E, and proceed as before. In like manner 032 is measured on 5 as two-thirds from OX or one-third from E, and 023 is obtained on 6 on the same principle as already described.

38. Assuming that we wish now to determine 710, 170, 530, 6.10.0, the final figure shows that these all lie in a zone parallel to *c*; they are therefore on *ab*. O*m* is to be produced, signed M, a perpendicular, 1, to be drawn to M from OX, and another, 2, perpendicular to OY. The cases in which the first index figure is greater than the second are to be measured on 2, and those on which it is less on 1. For 710 one-seventh of 2, measured from OY, gives the position, which is projected into *am* by a line radial to O. 170 is obtained by measuring one-seventh of 1 from OX. In the case of 530 the first and second figures are transposed, and three-fifths of 1 are measured from OX, or two-fifths of the same are to be measured from M. 6.10.0 is the same as 350 or as 12.20.0, just as 10.6.0 is the same as 530, and so on.

39. Now we are in a position to consider the cases in which the plane whose pole is to be determined cuts all three axes at distances less than unity. Suppose it is required to lay down 672, 953, 12.7.4, 6.10.3, which between them illustrate the principal cases. 672 can be shown to lie at the intersection of a line drawn from 670 to *c* with another line drawn from 602 or 301 to *b*. In like manner 953 lies at the intersection of a line from 950 to *c* with one from 903 or 301 to *b*. 12.7.4 in like manner is determined by drawing

a line from 12.7.0 to *c*, and intersecting it by a line from 12.0.4 or 301 to *b*. Again, 6.10.3 is found by intersections from 6.10.0 or 350 to *c* with 603 or 201 to *a*. In Crystallography these forms, which cut all three axes, are denoted by the general symbol (*hkl*). The poles of the zones in which these forms lie are not in any one of the planes of symmetry of the crystal.

40. The cases referred to embrace between them all those regarding which any difficulty is likely to be experienced by the beginner. In concluding this part of the paper, I would very strongly advise those who wish to master this important section of Crystallography to patiently follow these instructions. In the end, it will be evident that much mathematical work of a really useful kind has been done, and that, too, by the very simplest means possible under the circumstances. It is an excellent plan to make a large gnomonogram of the Cubic System, making the base a metre in width, and the other side those of a square, of which the base line is the diagonal. The point of contact with the spherical surface may be conveniently assumed to be on the middle of a perpendicular from the apex (*c*) of the triangle, and to represent the octahedron (111) *o*. Take *c* at the top, *b* at the right hand lower corner, and *a* on the left, *m* in the middle of the base line. With patience, and careful drawing of lines, the whole of all the indices up to fractions as high as $\frac{24}{25}$ths may be laid down simply by using intersection lines from and to the various cardinal positions already referred to. A map so constructed is a most valuable auxiliary to practical work afterwards.

41. The gnomonogram possesses many advantages over any of the other projections, most especially in regard to the facility it affords of drawing zones, and in readily determining the directions of intersections between any two faces. But it represents only one-eighth of the sphere of projection, or only one-twelfth in the case of the Rhombohedral System. Moreover, for the Monosymmetric System two separate gnomonograms are needed, and for the Anorthic four, and in both these cases the construction is much less

simple. There exists, therefore, need for a projection which does not possess these defects, and the only really satisfactory one that answers to the requirements is the Stereoscopic Projection, or what Lewis has named the STEREOGRAM.

42. The principle of construction is not difficult to understand. In the Gnomonogram, lines are supposed to be drawn from the centre of the sphere perpendicular to the faces of the crystal to be delineated, and the lines are supposed to pass outward from the surface of the sphere of projection until they touch a plane in contact with the sphere. In the Stereogram, lines are projected on to the surface of a sphere, as before, and the positions so marked are supposed to be viewed from a point at the opposite surface of the sphere. Lines drawn from the surface of the sphere to the point of sight pass through a diametral plane, which is perpendicular to the line joining the line of sight and the centre of the sphere. This plane is the PLANE OF PROJECTION in the present case, and it is inside the sphere, instead of outside, as it is in the projection last considered. By this method all zones are projected into either straight lines or else into arcs of circles—*not* into ellipses or into any other conic sections, as seems often to be supposed, and is really the case in both the Orthographic and the Globular projections.

43. The first step in the process is to draw a circle of such a radius as admits of easy division into decimal parts to not less than three places, and then to draw diameters at right angles to each other, which are prolonged to any convenient length beyond the primitive. The centre is to be signed O, and if the crystal is to be viewed from above, O will coincide with Z, and with the axis *c* if the crystal to be mapped belongs to any but the Monosymmetric and the Anorthic Systems. Let us assume that it is required to map an Orthorhombic crystal, as before. In that case, the front and back axis, on which *a* is to be, will be on some part of the diametral line in that position, and which, assumed to be of indefinite length, is signed X. The right and left, on which *b* will be determined presently, is to be signed Y. As we are now viewing the far side of the sphere of projection, the quadrants

may be distinguished as V., VI., VII., VIII., beginning at the bottom left hand, and going counter-clockwise. Next, we have to take into account the fact that for crystals of each species certain directions are determined by the behaviour of the crystal in relation to heat, light, electricity, magnetism, etc.—in other words, in relation to its molecular constitution, and that on this basis is decided what direction of the crystal shall be referred to *a, b, c* respectively. Further, that in each species of crystal the relative lengths of these axes, based upon the forms observed, is defined for each species. It is these relative lengths, *b* being taken as unity, which form the axial elements of the crystal, to which, in

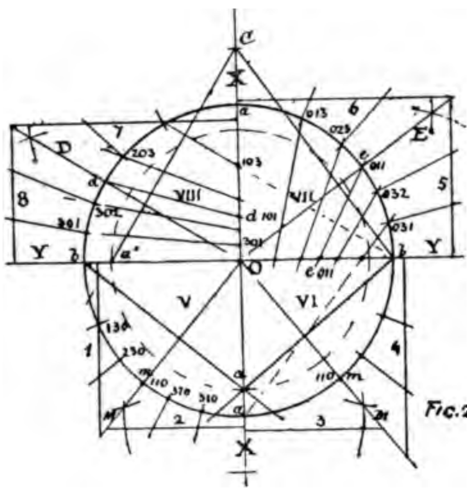


FIG. 2.

the Monosymmetric and the Anorthic crystals, has to be added the angular elements. Let us, as before, assume that it is required to make a map of Barytes, as viewed from above—in other words, a *c* projection. The relative lengths of the axes are—*a*, ·8152; *b*, 1; *c*, 1·31359, and the angular elements 90° in all three directions. Therefore, on OX, ·815 of the radius is carefully measured on either side of O, and a line is drawn from *b*, the radius on OY, through *a* to the opposite part of the primitive, and a perpendicular erected on that through O. It is well to do this in quadrant V. only. The line, as a whole, may be signed M, and the point where it cuts the primitive *m* (110). Set off the

distance that *m* is from OX on the corresponding points of the primitive in the other quadrants, and sign the lines *m* on the primitive and M on the indefinite continuation of the line. Draw parallels to OX and OY in V. and VI. at any convenient distance outside the primitive, figuring them 1 to 4, as before. Along these lines, as in the gnomonogram, the fractional parts for the prism zone *ab*, *ba*, are to be measured.

44. Next lay off the distance ·313 beyond the radius OX between VII. and VIII., and produce lines from *b* on VII. through this point. Draw a perpendicular from O through this line, marking the line as a whole E. Draw parallels to OX, OY, as before, to meet E at any convenient distance outside the primitive, and figure these parallels 5 and 6, as before. Next, in quadrant VIII., set off ·313 of the radius on OX beyond the primitive, between VII. and VIII.; and ·815 from O between V. and VIII.; join these points, and produce them to cut the primitive in V. Erect a perpendicular to pass from O outward, mark the line, supposed to be continued indefinitely, D, and draw parallels to OX, OY to meet OD as before, marking the lines 7 and 8. It is well to remark again, here, that we are at liberty to turn the sphere of projection about so as to view it in any direction; and as its boundaries are all represented by a circle, we may represent any octant of the sphere by any quadrant of the circle, and project from the part of the primitive in that quadrant, quite irrespective of the other. Thus the poles on *ca* are measured on 7 and 8, drawn thence to the primitive by lines directed to O, and from the primitive again projected on to OX between VII. and VIII. from the right-hand *b*, from which similarly-placed poles are set off with the compasses on the same line beyond O. In like manner, the poles on *bc* are measured on 5 and 6, are projected on to the primitive by lines radial to O, and are thence again projected by lines radial on *a* between 2 and 3 to *bc* between VI. and VII., from which the corresponding points on the opposite side of O are to be set off in their proper position. A reference to Fig. 2 will make this description clearer.

45. Before passing on to the description of the various

methods to be adopted in drawing arcs of circles, it may be well to refer to the Tables at the end of this paper, which are taken in part from Griffin's "Crystallography." These give the relative length of the lines which correspond to all the indices, except some of those of very rare occurrence. The Table is a valuable one, and will be found to save a large amount of labour.

46. Another device to serve the same purpose, and which I have used extensively, is on the same principle as the decimal scale already described. Instead of using the division on a metre scale, the proportional lengths corresponding to those given in the Table are set off from the metre scale, and are drawn convergent to a point some distance to the left of the drawing-paper used for the scale. The advantage of having such a scale is that one has only to measure off the distance to be divided up by sliding a set-square against a straight-edge placed parallel to the base until the unit length is intercepted, and then the length required for the fractional part can be measured off, and set out upon the working copy direct. It may be remarked that, owing to the large amount of geometrical work involved in a very complex map, it is hardly possible for even the most skilful draughtsman to complete a single copy of the map without its appearance having suffered from, various causes. Much of this may be avoided by a judicious use of these scales, and in most cases it is well to work out the lines on a separate map from that which is intended for the final copy.

47. Now, let us take those cases in which it is required to lay down the position of a pole which cuts all three axes. First we may take 111, *i.e.*, that face which cuts *a, b,* and *c,* each at unit length. To determine this, an arc of a circle has to be drawn. To do this, any one of various plans may be adopted. In most cases the arc may be described simply by finding the centre of the circle which will pass through the three points in question by the method commonly used, and then describing the curve with a pair of compasses, with a lengthening bar attached, if need be, or with the beam

compasses when the centre happens to be far off. An approximation to the position of the centre for the description of such arcs may be arrived at by a little contrivance I have used for some time. A rather large set-square is taken, and about a millimetre is cut up the obtuse, or right-angled corner. On the face of the square over this point, a small cork of firm texture is fastened at its base with seccotine, or other cement, and a fine needle is passed through it in such a manner that its point coincides with the intersection of the two rectangular sides of the square. The object is to enable one to rotate the set-square in its own plane, about its rectangular corner as a centre. Its use is to enable us to find the centre from which certain arcs of circles have to be described. Suppose we take the simple case just referred to, and wish to find the position of *o* (111) on the map. This lies at the intersection of an arc through *b* (010) and *d* (101) with a line from *m* (110) to *c* (001). To find the centre from which to describe the arc, we may in many cases make use of the set-square. The needle is placed at *a*, and the square moved around that point with its left edge cuts *d*, which is on the left side of the circumference of the circle required. In this position the right edge of the square on the prolongation of *cb* marks the right side of the circumference of the same circle. A point midway between this and *d* is the centre required. Another and a simpler method of finding the centres from which great circles inclined to the primitive may be described, is as follows:—Let O be the centre of the primitive, *a* the front-and-back diameter, and *b* another diameter cutting it at right angles, and let it be required to describe, on the left side, the projections of two great circles *f* and *g*, respectively inclined 20° and 70° to the primitive. In the lower right-hand quadrant set off ·347 of the radius from *b*, and sign the point F; produce O*b* indefinitely to the right; from F erect a perpendicular to FO, cutting the extension of O*b* at F. Likewise set off in the same quadrant 1·147 of the radius from *b*, and sign it G; erect a perpendicular to GO, cutting O*b* in G. Then, with the radius F*a* describe the projection *f*, and with that of G*a* describe the required projection *g*.

48. In the very common case in which the centres of the arcs required are at too great a distance to be drawn with compasses, even when eked out by the lengthening bar, some other device must be employed. This is usually difficult to do, and the difficulty is increased by the fact that all the curved lines in the stereogram must be arcs of great circles, so that a merely smooth curve connecting any three points is not necessarily all that is required. In practice, it is often sufficient for us to determine accurately the position of a sufficient number of points which lie exactly within the required arc, and then to connect these points by a curve drawn in by hand—the only really essential feature being that the *points* shall be correctly laid down in an arc of a great circle.

49. One simple device which answers well in those cases in which the height or rise of the arc is not very small, is to draw, on a separate piece of cardboard, a line equal in length to about two diameters of the primitive. Mark the centre, set off the length of the radius on each side for the "span" of the arc, and then erect a perpendicular above the middle point, which shall be equal in length to the height of the arc required to be drawn. From the "rise" thus determined, draw a line to one extremity of the "span," and another line parallel to and above the other extremity of the "span." With a sharp knife, against a steel straight-edge, make a clean cut along the two lines thus drawn. If, now, two slender needles are fixed in the diametral points in the primitive through which the required curve has to pass, and the cardboard triangle be moved in its own plane in contact with these needle-points, the apex of the triangle will pass through the arc of the great circle required, and any desired number of points in that arc can be laid down. In practice this answers very well if no attempt be made to draw the curve directly by the aid of this instrument. If the triangle be varnished, it may be used many times for arcs of the same "span" and "rise."

50. Another device is to employ a set of the cardboard curves cut to various radii, which are used by engineers for laying down railway curves upon their working plans.

They give most excellent results in all cases where they happen to fit. The arcs of circles on the maps I have made for Heddle's "Mineralogy of Scotland" were mostly drawn by means of the set of railway curves belonging to the Edinburgh Museum of Science and Art.

51. The principle upon which yet another device is employed may be best understood by drawing the ends of a flexible rod towards each other against two fulcra. If the rod is exactly uniform in structure and in dimensions throughout its entire length, and is flexed by equal force at each end, the curve into which it is thus bent will be an arc of a circle, by which means a curve of the required form can easily be drawn on the map. Many instruments have been constructed upon this principle. In practice, a slender and flexible steel straight-edge, uniform in width and thickness, and equal in length to about four radii of the primitive, is the best for the purpose, and the fulcra employed may be two small brass studs fixed on a strip of metal at a distance equal to three radii of the primitive. It is important to bear in mind that a thrust from any single point *between* the fulcra will give a curve which is *not* an arc of a circle. Some well-known books on Crystallography have seriously misled their readers in this connection.

52. After the description already given of the mode of finding the positions of poles which cut all three axes—a case for which the general symbol (*hkl*) is employed in Crystallography—there is no need to repeat the direction here. What applies to the more-easily-constructed gnomonogram applies equally to the cases specially under consideration here, only that arcs of circles have to be drawn instead of straight lines.

53. We may now pass on to consider the mode of constructing stereograms of Monosymmetric crystals, a process which requires more care and labour than any constructions yet noticed, and up to which, in fact, much of the foregoing description is really meant to lead.

54. We may first advantageously consider the principles which underlie the construction in the case under considera-

tion. In the system just noticed, the vertical axis is taken as being at right angles to both the others, while in the Monosymmetric system, what is usually taken as the vertical axis is inclined. But for a right understanding of what is to follow here, the reader is asked to conceive of there being *two* sets of axes present—one normal, and of the same nature as in the Orthorhombic system; and another, in which the right and left axis b remains unchanged in direction, while the vertical axis c is inclined, usually forward at the top, and the back-and-front axis a, still at right angles to the last-named, is inclined in front below the horizontal front-and-back axis. The inclination of the plane containing ob, and the inclined axis to the plane containing ob and the vertical axis, varies, like the length of the axis, with each species. It is usual to distinguish the angle which these two planes form with each other by β—the angle being measured from below, on the front side. Therefore the angle which the inclined c axis makes with the vertical or zc axis is equal to a right angle minus the angle denoted by β, or, in other words, is the complement of that angle. Furthermore, the inclined angles when projected from the sphere on to the plane of projection are fore-shortened to β in a manner that will be more fully described further on.

55. We may view the sphere of projection from any point on its surface. We might, for example, suppose the eye to be placed at a, and the poles to be projected on to the right and left vertical plane, passing through the centre; no specially useful purpose would be gained by employing such a projection. Or we might view it from above, and conceive, as is usually done with the projections of all the systems with rectangular axes, that the poles are all projected from the under surface of the sphere on to the horizontal plane passing through the centre. This is often done, and the c projection, as it is termed, is often as useful in the present case as it is in the others. Lastly, we might suppose the eye to be placed at b, with a right and left, and c vertical; in which case the poles on the four quadrants at the back of the sphere, as they would appear if viewed on its concave surface, are supposed to be projected upon a plane contain-

ing O*ca*. This construction is known as the *b* projection, and as it is more commonly employed than the last-named, and as the principles of monosymmetric projection are more easily grasped by considering this one first, it will be taken in this place.

56. As before, choose a radius of any length which can be conveniently divided into decimal parts to three places, by proportional compasses, by the decimal scale already described, or by means of a good diagonal scale. Describe a circle with this radius, divide it into quadrants by lines at right angles to each other passing through O, the origin or centre, as before. These lines are to be understood to be of indefinite length. Mark each extremity of the right and left axis X, and each extremity of the vertical axis Z, as before. Mark the bottom left-hand quadrant with the Roman numeral V., and the other three, counter-clockwise, respectively VI., VII., VIII., as they represent the forms on the quadrants at the back of the sphere. (It may be remarked here that the construction lines for stereograms in general, and especially those intended for the Monosymmetric maps, are better drawn first on a separate sheet of paper from that intended for the finished map.)

57. Let us take a *b* projection of Hornblende, as a convenient mineral to begin with. For this the axial elements are—*a*, ·55108; *b*, 1; *c*, ·29376; and the angular elements are O*b* - O*a*, 90°; OZ - O*a* (or β), 73° 58′. O*b* (the radius) being unity, the chord of β is 1·2032. Take this distance from the decimal scale with the dividers, and mark it on the primitive in quadrants V. and VII., measuring from OZ; do the same in VI. and VIII. from OX. Draw diameters through these points on the primitive: the line passing through V. and VII. will be that on which A will be measured, and that through VI. and VIII. will represent C. Now set off ·293 on Z on either side of O, and mark these points C; also set off ·551 on either side of O on the inclined axis in V. and VII., and mark these points A. Join AC on all four sides, and produce the lines both ways so as to cut the primitive, and from the points where they do so describe intersecting arcs of any convenient radius, and through these points draw lines

outward from O, marking the point where the one line cuts the primitive in VII. and VIII. as 101 (*d*), and its continuation beyond as D in both quadrants. (See Fig. 3, in which the axial lengths, however, are arbitrarily chosen.)

58. Next, with a set-square, mark off on the inclined axis in VI. and VIII. the points where a right angle to that line cuts C, above and below O, and sign the point with an italic capital *C* in both quadrants; also mark the point where the inclined axis O*C* cuts the primitive in both VIII. and VI., and sign them with a small italic *c*, which marks the position of (001) on the circle of projection (see Fig. 3).

59. In like manner, in quadrants V. and VII., draw perpendiculars from OX to A, and sign these points on OX with a capital italic *A*, and the point where this line cuts the primitive *a*. This last marks the position of the pole (100) on to the circle of projection. Draw a line parallel to OX at any convenient distance outside the circle of projection, and

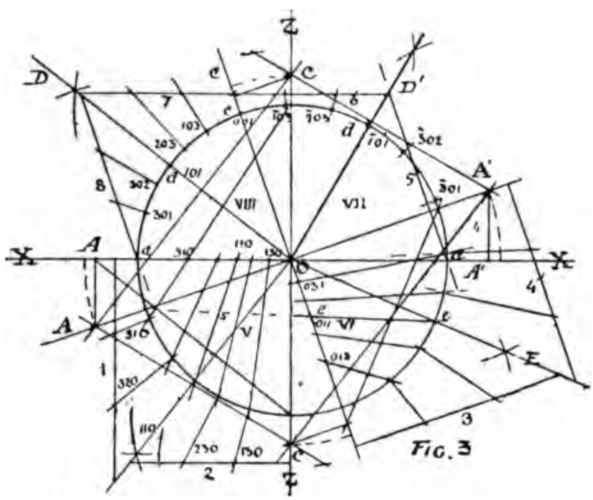


FIG. 3

produce it each way to touch either D. Figure that to the right of C (6), and that to the left (7). Also draw lines from either *a* parallel to OC to touch D, mark the one to the right hand (5), and that to the left (8). It is along these lines 5, 6, 7, 8, that the positions of all the poles in the zone *ca*, front and back (or positive and negative), are first measured in

the manner already described in the previous cases, and are thence projected on to the primitive by lines radial to O—the proportional distances being taken from the fractional scale described in paragraph 46. Positions so determined are, as before, set off upon the corresponding quadrants on the opposite side of the circle.

60. We have next to determine the positions of the poles in the prism zone (*ab*) which lies on the line OX. The sphere of projection for this purpose is now supposed to be turned round, and viewed from *c*. Quadrant V. is set apart for that aspect of the sphere. A line is drawn from *A* in that quadrant (see Fig. 3) to the point where OZ cuts the primitive—this point representing the extremity of the axis *b* (which is taken as unity) between V. and VI. This represents the direction of the unit prism face *m* (110) as viewed from *c*. A perpendicular is drawn to this line outward from O, the point where it cuts the primitive is marked *m*, and the outward continuation of the line M. Parallels to OX, OZ, are drawn at any convenient distance outside of the primitive from OX, OZ, to meet M. Number these lines *a*M as 1, and M*c* as 2. Intercepts between *a* and *m* are measured upon 1, and those between *m* and *b* upon 2. When these are determined, lines are drawn from the respective points to the primitive radial to O, and then from these points on the primitive they are projected on to *ab* by lines radial to where OZ cuts the primitive between VII. and VIII., as shown by the dotted lines on Fig. 3. These points, so determined, mark the projection of the poles of the several prisms on the *b* projection, and are to be set off on either side of O.

61. Lastly, we require to determine the positions of the poles on (*bc*). For this purpose we must remember that we are at liberty to conceive of the sphere of projection being turned about so as to be viewed in any position, and we may thus devote another quadrant to the projection of the poles as viewed from a position different from either of the others. Quadrant VI. is to be used for the projection of the zones in that aspect. The inclination of the *a* axis in this case has no effect upon the projection, beyond the foreshortening of *c*. To determine the cardinal pole *e*, we have, therefore, first

to draw a line at right angles to the o*C* axis in VI. from the *c* on the OZ axis, and from this foreshortened *C* draw a line to the point where OA cuts the primitive in VII. A perpendicular to this line drawn outward from O is to be signed E, and *e* where it cuts the primitive. Then from the opposite point where o*a* cuts the primitive, which is the point of sight in this case, a line to *e* will project the required position of *e* (011) upon o*C*. Draw parallels at any convenient distance outside of the primitive to o*C*, OA, and measure off proportional lengths upon these, as in the former cases. From these points so determined draw lines radial to *o* to cut the primitive, and from these, in their turn, draw lines radial to the point of sight, and where they cut o*C* is the position required.

62. In each of these cases a study of Figure 3 will further elucidate the method. It appears tedious and complicated when expressed in words and in a non-mathematical form; but in actual practice no real difficulty ought to be met with.

63. The remainder of the construction has been already described, and consists of little more than drawing two arcs of great circles each through three given points, which by their intersection give the positions of the poles required.

64. It is sometimes convenient to employ a map of a monosymmetric crystal drawn on the *c* projection—on the whole I prefer this. The usual objection urged against it is that it is more difficult to construct than the *b* projection, and that it does not show the monoclinic character quite so clearly. These objections seem to me to possess but little weight. One way to do is to make use of *both*; and in the maps I have drawn for "The Mineralogy of Scotland," of which an example is appended to this paper, the advantage of this plan will, I think, be sufficiently manifest.

65. We may conveniently choose Hornblende as the species to be mapped on the *c* projection. For this purpose draw a circle of convenient radius as before, and draw in diameters at right angles to each other, marking their extremities (which may be of any length outside the primitive), X in the case of the front and back axis, and Y in the right and left, and the centre O. From O as a centre, with a

radius equal to ·551 of the unit, describe a circle, and mark it, anywhere, *a*; and from the same centre, with radius ·293 of the unit, describe another circle, and sign it *c*. These are required, because *ac*, *bc* will need to be viewed respectively, in two different aspects. We may distinguish the quadrants, as before, by roman numerals—V., VI., VII., VIII.—taken counter-clockwise, starting with the front left hand one. Where OX cuts the primitive between V. and VI. and VII. and VIII., mark *a*, and mark *b* in the corresponding position at right angles to these. We may devote quadrant VI. to the projection of the prism zone. Join the point where the circle *a* cuts OX, with the right hand *b*, and produce the line to cut the primitive in V. On this line erect a perpendicular radial to O, cutting the primitive at a point to one marked *m* (110), and extended outward to any convenient length M. Parallels to *ob*, *oa* are drawn to meet M, and may be figured as 3 and 4, for convenience of reference, if need be. Their use is, of course, to determine the positions of the poles in the prism zone, and has been sufficiently described already. The distances on the primitive are to be marked off in corresponding positions in each quadrant, as before.

66. The poles on *cb* have next to be laid down. We can do this by a direct method presently to be described; but at this stage it is better to project their relative positions on to O*b*, and afterwards carry them on to their correct position by arcs of circles passing through those points and *a*. Quadrant VII. is devoted to this, and in this we are supposed first to view the sphere of projection from the side at *a*. From *b* in VII. draw a line through the circle *c*, where it cuts OX between VII. and VIII., and produce the line to cut the primitive in VIII. From O erect a perpendicular to this line, and produce it beyond the primitive, signing it E. A radial from the point where E cuts the primitive through O*b* to the front *a* will cut O*b* in the position from which *e* (011) can afterwards be readily drawn. Also draw parallels to O*a*, O*b*, to meet E, and figure them 5, 6, for convenience of reference. They, of course, are to be used for measuring the proportional lengths corresponding

to the indices in the *cb* zone, and are projected in the manner already sufficiently described, from the point of sight represented by the front *a*. The method just referred to, of determining the projections of poles whose angular (or whose proportional) distance from a given point on the projection of a great circle inclined to the primitive is known, is as follows:—Let O be the centre, aa^1 the front-and-back diameter, bb^1 the diameter right-and-left, and *d* the projection of the inclined great circle, cutting the primitive at bb^1; and that it is required to lay down the position of a pole *e* on *d* at a given angular (or a given proportional) distance from *b*. From b^1 draw a right line through the point where *d* cuts Oa^1 and produce it from the primitive, and from the point so determined set off upon the primitive towards *a* the chord of a quadrant. Then, from this point draw a right line to b^1. The point where it intersects O*a* is the projection of the POLE, *p*, of the inclined great circle *d*. Then, from *b* set off the given angular (or the given proportional) distance of *e* from *b*, signing it E. Join E*p*, and the point where this line cuts the great circle *e* is the projection required. This method is much used in constructing maps of monosymmetric and of anorthic species.

67. Finally, there remains the zone *ac*, with its positive and negative poles. For these the quadrants V. and VIII. are reserved, and we are supposed in this case to be viewing the sphere of projection from *b*, and that the line *a*O*a* represents the trace of the plane of projection upon which these poles are to be drawn, and that *b* on the right is the position of the point of sight. The earlier stages, at least, of the work are most clearly comprehended by turning the map round and placing *b*, the point of sight, at the bottom, and thus reading OX as OZ, O and Y will therefore coincide in this position. *A* will change places with *A*, and A with C, in this reading in the new position. From the point where the circle *a* cuts OX, draw a line which is at right angles to OA (quadrant VI.), and from this point draw a line through the point where the circle *c* cuts OY (or OZ in the new position), and produce the line on either side to cut the primitive; from each point where it does

so, describe intersecting arcs with any convenient radius, and draw a line radial to O outwards, marking it D. From the point where this line cuts the primitive, draw a line towards the point of sight, which will cut OX in the position of *d* (101).

68. To project the corresponding point on the negative side, *d* (101), set off a rectangle in VIII. from the inclined axis OA, as before, to cut the point where the circle *a* crosses OX (on the right hand side in the present position), and join the point where the circle *c* cuts O*b*, as before, producing the line on either side to cut the primitive, erect a perpendicular from O, and, as before, project from the point of sight on to O*a*, whereby *d* (101) is found. To determine positions between either *d*, and *c*, or *a*, lines through *a*, on either side parallel to *c*, have to be produced until they meet D on each side, and another, parallel to O*a*, has to be drawn also to meet D on each side. Mark a cross where O*c* crosses this line, so as to indicate where measurements on the negative or the positive side of *c* are to commence. Now project *c* on to the primitive by a line radial to O, and from the primitive by a line radial to the point of sight into *a-a*. The uses of all these lines having been already explained, it only remains to add that arcs of circles have to be drawn for the zones in all cases, except that representing the trace of the plane of symmetry, which passes through *aca*. To project the points determined from *cb* zone, arcs of circles must be drawn through each of these points and *a*, front and back. Then arcs of circles must be drawn through each *b* and the several points on the line *a*O*a*, commencing with the projection of *c*. Next, arcs of circles must be drawn through *m* (110) and *c* (001), and so on, as already described, in the simpler cases taken earlier in the present paper.

69. It is often required to find the centre from which to describe an arc of a great circle which shall pass through two points, *m* and *n*, within the primitive. This is done as follows:—Let O be the centre; join *m*O, *n*O, and produce these lines indefinitely beyond the primitive. From O erect perpendiculars to *m*O, *n*O, signing the points where these lines cut the primitive respectively *M*, *N*. From *M* and *N* erect perpendiculars to *Mm*, *Nn*, and produce these lines

until they touch the prolongation of mO, nO; sign these points respectively p, q. Then the pairs mp, nq are points in the circumference of the great circle required. Erect perpendiculars upon the middle of the chords mp, nq, and produce them until they meet. The point thus determined is the centre required.

70. In conclusion, it only remains for me to remark that this very elementary and somewhat lengthy description is not put forward for the use of mathematicians, who already know (or can easily do so, if they choose) how to work out all these problems by methods much neater, briefer, and, in some cases, more precise, than those advanced here. Many subjects have been intentionally left unreferred to, simply because their complexity might cause confusion at the outset. After doing a little practical work on the lines here laid down, the student will gradually feel his way to dealing with maps of crystals belonging to the Anorthic System, and to draw even these by geometrical methods and PROPORTIONAL MEASUREMENT, such as I have dealt with in the simpler cases here described.

71. Lastly, it will be observed that I have rarely made use of *angular* measurements. That has been intentional. In Crystallography we are concerned with proportions and directions much more than with angular measurements. Anyone who will glance at the Tables at the end will see that these factors in Crystallography are certainly not commensurate with those commonly employed in angular measurements in general. They belong, in fact, to a different order, which has its basis in the molecular constitution of the crystal. To lose sight of this fact is, I think, to close our eyes to the gradually increasing light which is rendering new paths in molecular science visible to our view.

The Maps appended to this—a gnomonogram of Quartz, a c projection of Barytes, and both b and c projections of Orthoclase—will exemplify the projections described in the paper. They are part of a set drawn for Heddle's "Mineralogy of Scotland," and are inserted here through the courtesy of Mr Alex. Thoms, of St Andrews, and the publishers of the work, the Messrs Douglas, of Edinburgh.

The following Table gives all the commoner indices up to 49.50.0, 49.0.50 in the form of fractions, together with their decimal equivalents, which represent the proportional lengths to radius as unity, and are the natural tangents to the angles represented by the indices. The nearest angular measurement in degrees and minutes to these is given in the first column.

The Table is taken partly from Griffin's "Principles of Crystallography," with some extensions, and with some omissions of the parts not needed for the present purpose.

° ′			° ′			° ′		
			1·50	022008		3·57	0690	$\frac{2}{29}$
1·09	019783			032258	$\frac{1}{31}$	4·00	0699	
	020000	$\frac{1}{50}$	1·53	032882		4·05	0714	$\frac{1}{14}$
1·10	020365			033333	$\frac{1}{30}$	4·14	0740	$\frac{2}{27}$
	020408	$\frac{1}{49}$	1·57	034047		4·24	0769	$\frac{1}{13}$
1·11	020656			034482	$\frac{1}{29}$	4·34	0799	$\frac{2}{25}$
	020833	$\frac{1}{48}$	2·0	034920		4·46	0834	$\frac{1}{12}$
1·13	021238			035714	$\frac{1}{28}$	4·54	0857	$\frac{3}{35}$
	021276	$\frac{1}{47}$	2·3	035794		4·58	0869	$\frac{2}{23}$
1·14	021529			037037	$\frac{1}{27}$	5·00	0875	
	021739	$\frac{1}{46}$	2·08	037250		5·12	0910	$\frac{1}{11}$
1·15	021820			038461	$\frac{1}{26}$	5·21	0936	$\frac{3}{32}$
	022222	$\frac{1}{45}$	2·14	038998		5·26	0951	$\frac{2}{21}$
1·17	022402			040000	$\frac{1}{25}$	5·32	0969	$\frac{3}{31}$
	022727	$\frac{1}{44}$	2·18	040164		5·42	0998	$\frac{1}{10}$
1·19	022984			040816	$\frac{2}{49}$	5·54	1033	$\frac{3}{29}$
	023255	$\frac{1}{43}$	2·21	041038		6·00	1051	
1·21	023566			041666	$\frac{1}{24}$	6·01	1054	$\frac{2}{19}$
	023809	$\frac{1}{42}$	2·24	041912		6·20	1110	$\frac{1}{9}$
1·23	024148			042552	$\frac{2}{47}$	6·31	1142	$\frac{4}{35}$
	024390	$\frac{1}{41}$	2·29	043369		6·43	1178	$\frac{2}{17}$
1·25	024730			043478	$\frac{1}{23}$	6·51	1201	$\frac{3}{25}$
1·26	025000	$\frac{1}{40}$	2·33	044535		7·00	1228	
1·27	025312			045454	$\frac{1}{22}$	7·07	1249	$\frac{1}{8}$
	025601	$\frac{1}{39}$	2·38	045992		7·21	1290	$\frac{4}{31}$
1·29	025894			046510	$\frac{2}{43}$	7·26	1305	$\frac{3}{23}$
	026186		2·42	047158		7·36	1334	$\frac{2}{15}$
1·30	026315	$\frac{1}{38}$		047619	$\frac{1}{21}$	7·46	1363	$\frac{3}{22}$
1·33	027027	$\frac{1}{37}$	2·47	048616		8·00	1405	
1·35	027641			048780	$\frac{2}{41}$	8·03	1414	
	027778	$\frac{1}{36}$	2·51	049782		8·08	1429	$\frac{1}{7}$
1·37	028223			050000	$\frac{1}{20}$	8·18	1459	$\frac{7}{48}$
	028571	$\frac{1}{35}$	2·52	050074		8·26	1483	$\frac{4}{27}$
1·39	028805		3·00	0524		8·32	1500	$\frac{3}{20}$
	029441	$\frac{1}{34}$	3·01	0527	$\frac{1}{19}$	8·45	1539	$\frac{2}{13}$
1·42	029679		3·11	0556	$\frac{1}{18}$	8·58	1578	$\frac{3}{19}$
	030303	$\frac{1}{33}$	3·22	0588	$\frac{1}{17}$	9·00	1584	
1·45	030552		3·35	0626	$\frac{1}{16}$	9·06	1602	$\frac{4}{25}$
1·48	031250	$\frac{1}{32}$	3·49	0667	$\frac{1}{15}$	9·13	1623	$\frac{6}{37}$

° ′			° ′			° ′		
9·28	1667	$\frac{1}{6}$	15·48	2830		21·37	3963	
9·41	1706	$\frac{7}{41}$	15·57	2858	$\frac{2}{7}$	21·46	3993	
9·52	1739	$\frac{4}{23}$	16·00	2867		21·47	3996	
10·00	1763	$\frac{3}{17}$	16·09	2896	$\frac{11}{38}$	21·48	4000	$\frac{2}{5}$
10·01	1766		16·16	2918	$\frac{7}{24}$	22·00	4040	
10·02	1769		16·23	2940	$\frac{5}{17}$	22·01	4044	
10·06	1781		16·30	2962	$\frac{8}{27}$	22·10	4074	$\frac{11}{27}$
10·12	1799	$\frac{9}{50}$	16·42	3000	$\frac{3}{10}$	22·13	4084	
10·18	1817	$\frac{2}{11}$	16·46	3013		22·15	4091	$\frac{9}{22}$
10·26	1841	$\frac{7}{38}$	16·47	3016		22·23	4118	$\frac{7}{17}$
10·36	1871		16·56	3045	$\frac{7}{23}$	22·30	4142	
10·37	1874	$\frac{3}{16}$	17·00	3057		22·37	4166	$\frac{5}{12}$
10·47	1905	$\frac{4}{21}$	17·06	3076	$\frac{4}{13}$	22·45	4193	
10·53	1923	$\frac{5}{26}$	17·10	3089		22·50	4210	$\frac{8}{19}$
11·00	1944	$\frac{7}{36}$	17·21	3124	$\frac{5}{16}$	22·56	4231	$\frac{11}{26}$
11·10	1974		17·32	3159	$\frac{6}{19}$	23·00	4245	
11·18	1998		17·39	3182	$\frac{7}{22}$	23·04	4258	
11·19	2001	$\frac{1}{5}$	17·45	3201	$\frac{8}{25}$	23·05	4262	
11·32	2041		17·53	3227	$\frac{10}{31}$	23·08	4272	
11·34	2047	$\frac{9}{44}$	17·56	3236		23·12	4286	$\frac{3}{7}$
11·36	2053	$\frac{8}{39}$	18·00	3249	$\frac{13}{40}$	23·30	4348	$\frac{10}{23}$
11·46	2083	$\frac{5}{24}$	18·12	3288		23·35	4365	
11·53	2104	$\frac{4}{19}$	18·16	3301		23·38	4376	$\frac{7}{16}$
12·00	2126		18·18	3307		23·45	4400	$\frac{11}{25}$
12·06	2144	$\frac{3}{14}$	18·26	3333	$\frac{1}{3}$	23·58	4445	$\frac{4}{9}$
12·16	2174	$\frac{5}{23}$	18·41	3382		24·00	4452	
12·23	2196	$\frac{9}{41}$	18·56	3430		24·03	4463	
12·32	2223	$\frac{2}{9}$	18·58	3437	$\frac{11}{32}$	24·04	4466	
12·36	2235		19·00	3443		24·05	4470	
12·41	2251	$\frac{9}{40}$	19·01	3447	$\frac{10}{29}$	24·06	4473	
12·48	2272	$\frac{5}{22}$	19·02	3450		24·14	4501	$\frac{9}{20}$
13·00	2309	$\frac{3}{13}$	19·06	3463		24·27	4547	$\frac{5}{11}$
13·08	2333	$\frac{7}{30}$	19·07	3466		24·30	4557	
13·14	2352	$\frac{4}{17}$	19·11	3479	$\frac{8}{23}$	24·37	4582	$\frac{11}{24}$
13·24	2382	$\frac{5}{21}$	19·17	3499	$\frac{7}{20}$	24·42	4599	$\frac{23}{50}$
13·27	2392		19·26	3528	$\frac{6}{17}$	24·46	4614	$\frac{6}{13}$
13·28	2395		19·28	3535	$\frac{29}{82}$	25·00	4663	
13·30	2401	$\frac{6}{25}$	19·29	3538		25·01	4667	$\frac{7}{15}$
13·38	2425		19·32	3548	$\frac{11}{31}$	25·12	4706	$\frac{8}{17}$
13·43	2441	$\frac{10}{41}$	19·39	3571	$\frac{5}{14}$	25·14	4713	
13·53	2472		19·48	3600	$\frac{9}{25}$	25·15	4716	
13·54	2475		19·59	3636	$\frac{4}{11}$	25·21	4738	$\frac{9}{19}$
14·00	2493		20·00	3640		25·28	4763	$\frac{10}{21}$
14·01	2496		20·08	3666	$\frac{11}{30}$	25·34	4784	$\frac{11}{23}$
14·02	2499	$\frac{1}{4}$	20·13	3683	$\frac{7}{19}$	25·39	4802	$\frac{12}{25}$
14·17	2546		20·19	3702	$\frac{10}{27}$	25·47	4831	$\frac{14}{29}$
14·23	2564	$\frac{10}{39}$	20·30	3739		25·48	4834	
14·30	2586		20·33	3749	$\frac{3}{8}$	26·00	4877	
14·37	2608	$\frac{6}{23}$	20·51	3809	$\frac{8}{21}$	26·11	4917	
14·45	2633	$\frac{5}{19}$	20·56	3825		26·20	4950	
14·56	2667	$\frac{4}{15}$	20·57	3829		26·30	4986	
15·00	2679		21·00	3839		26·34	5000	$\frac{1}{2}$
15·01	2683	$\frac{11}{41}$	21·02	3845	$\frac{5}{13}$	26·40	5022	
15·15	2726	$\frac{3}{11}$	21·10	3872		26·50	5059	
15·30	2773		21·15	3889	$\frac{7}{18}$	27·00	5095	
15·31	2776		21·20	3906		27·13	5143	
15·32	2780	$\frac{5}{18}$	21·22	3912	$\frac{9}{23}$	27·21	5172	$\frac{15}{29}$
15·39	2801	$\frac{7}{25}$	21·30	3939		27·22	5176	
15·47	2827		21·36	3959		27·28	5198	$\frac{13}{25}$

° ′			° ′			° ′		
27·30	5206		32·37	6399	$\frac{16}{25}$	37·52	7775	$\frac{7}{9}$
27·31	5209		32·38	6403		38·00	7813	
27·33	5217	$\frac{13}{25}$	32·39	6408		38·03	7827	$\frac{18}{23}$
27·39	5239	$\frac{11}{21}$	32·44	6428	$\frac{9}{14}$	38·09	7855	$\frac{11}{14}$
27·41	5246		32·50	6453		38·18	7898	$\frac{15}{19}$
27·42	5250		32·53	6465		38·22	7916	$\frac{19}{24}$
27·43	5254		32·55	6473	$\frac{11}{17}$	38·30	7954	
27·46	5265	$\frac{10}{19}$	32·59	6490		38·39	7997	
27·54	5295	$\frac{9}{17}$	33·00	6494		38·40	8002	$\frac{4}{5}$
28·00	5317		33·01	6498	$\frac{13}{20}$	38·50	8050	
28·04	5332	$\frac{8}{15}$	33·07	6523	$\frac{15}{23}$	38·59	8093	$\frac{17}{21}$
28·18	5384	$\frac{7}{13}$	33·12	6544		39·00	8098	
28·20	5392		33·13	6548		39·02	8107	
28·21	5396		33·24	6594		39·06	8127	$\frac{13}{16}$
28·27	5418	$\frac{13}{24}$	33·34	6636		39·14	8165	
28·35	5448		33·41	6665		39·18	8185	$\frac{9}{11}$
28·37	5456	$\frac{6}{11}$	33·42	6669	$\frac{2}{3}$	39·28	8234	$\frac{14}{17}$
28·38	5460		33·50	6703		39·34	8263	$\frac{19}{23}$
28·39	5464		33·59	6741		39·48	8332	$\frac{5}{6}$
28·49	5501	$\frac{11}{20}$	34·00	6745		39·58	8381	
29·00	5543		34·13	6800	$\frac{17}{25}$	40·00	8391	
29·03	5555	$\frac{5}{9}$	34·17	6817	$\frac{15}{22}$	40·02	8401	$\frac{21}{25}$
29·12	5589		34·22	6839		40·06	8421	$\frac{16}{19}$
29·15	5600	$\frac{14}{25}$	34·23	6843	$\frac{13}{19}$	40·14	8461	$\frac{11}{13}$
29·22	5627	$\frac{9}{16}$	34·31	6877	$\frac{11}{16}$	40·22	8501	$\frac{17}{20}$
29·29	5654	$\frac{13}{23}$	34·42	6924	$\frac{9}{13}$	40·26	8521	
29·30	5658		34·49	6954	$\frac{16}{23}$	40·36	8571	$\frac{6}{7}$
29·40	5696		34·59	6998		40·49	8637	$\frac{19}{22}$
29·45	5715	$\frac{4}{7}$	35·00	7002	$\frac{7}{10}$	40·55	8667	$\frac{13}{15}$
29·59	5770	$\frac{15}{26}$	35·13	7059	$\frac{12}{17}$	41·00	8693	
30·00	5774		35·16	7072	$\frac{29}{41}$	41·01	8698	$\frac{20}{23}$
30·04	5789	$\frac{11}{19}$	35·19	7085	$\frac{17}{24}$	41·11	8749	$\frac{7}{8}$
30·10	5812		35·22	7098		41·21	8801	$\frac{22}{25}$
30·15	5832	$\frac{7}{12}$	35·30	7133		41·23	8811	
30·28	5883	$\frac{10}{17}$	35·32	7142	$\frac{5}{7}$	41·24	8816	
30·35	5910	$\frac{13}{22}$	35·45	7199	$\frac{18}{25}$	41·25	8821	$\frac{15}{17}$
30·41	5934		35·50	7221	$\frac{13}{18}$	41·34	8668	
30·50	5969		36·00	7265		41·38	8889	$\frac{8}{9}$
30·58	6001	$\frac{3}{5}$	36·02	7274	$\frac{8}{11}$	41·48	8941	
30·59	6005		36·15	7332	$\frac{11}{15}$	41·49	8946	$\frac{17}{19}$
31·00	6009		36·23	7368	$\frac{14}{19}$	41·59	8999	
31·10	6048		36·24	7373		42·00	9004	$\frac{9}{10}$
31·20	6088	$\frac{14}{23}$	36·28	7391	$\frac{17}{23}$	42·08	9046	$\frac{19}{21}$
31·23	6100		36·42	7454		42·10	9057	
31·24	6104		36·43	7458		42·16	9089	$\frac{10}{11}$
31·26	6112	$\frac{11}{18}$	36·44	7463		42·17	9094	
31·29	6124		36·52	7499	$\frac{3}{4}$	42·24	9131	$\frac{21}{23}$
31·35	6148		36·53	7504		42·29	9158	
31·36	6152	$\frac{8}{13}$	37·00	7536		42·31	9169	$\frac{11}{12}$
31·45	6188	$\frac{13}{21}$	37·14	7600	$\frac{19}{25}$	42·36	9195	
31·52	6216		37·18	7618	$\frac{16}{21}$	42·37	9201	$\frac{23}{25}$
31·57	6237		37·24	7646	$\frac{13}{17}$	42·42	9228	$\frac{12}{13}$
32·00	6249	$\frac{5}{8}$	37·28	7664		42·49	9266	
32·01	6253		37·34	7692	$\frac{10}{13}$	42·53	9287	$\frac{13}{14}$
32·10	6289		37·38	7710		43·00	9325	
32·17	6318	$\frac{12}{19}$	37·42	7729	$\frac{17}{22}$	43·01	9331	$\frac{14}{15}$
32·18	6322		37·45	7743		43·09	9374	$\frac{15}{16}$
32·19	6326		37·46	7747		43·10	9380	
32·28	6363	$\frac{7}{11}$	37·49	7761		43·14	9402	$\frac{47}{50}$

° ′			° ′			° ′		
43·16	9413	$\frac{16}{17}$	43·53	9618	$\frac{25}{26}$	44·30	9827	
43·18	9424		43·54	9623		44·35	9856	
43·19	9429		43·55	9629	$\frac{26}{27}$	44·40	9884	
43·22	9446	$\frac{17}{18}$	43·57	9640	$\frac{27}{28}$	44·43	9002	
43·27	9473	$\frac{18}{19}$	44·00	9657	$\frac{28}{29}$	44·50	9942	
43·32	9501	$\frac{19}{20}$	44·01	9663	$\frac{29}{30}$	44·55	9971	
43·36	9523	$\frac{20}{21}$	44·02	9668		44·56	9977	
43·40	9545	$\frac{21}{22}$	44·04	9679	$\frac{30}{31}$	44·57	9983	
43·44	9567	$\frac{22}{23}$	44·11	9719	$\frac{35}{36}$	44·58	9988	
43·47	9584	$\frac{23}{24}$	44·18	9759	$\frac{40}{41}$	44·59	9994	
43·50	9601	$\frac{24}{25}$	44·22	9781	$\frac{45}{46}$	45·00	1·00	
43·51	9606		44·25	9798	$\frac{49}{50}$			

EXPLANATION OF PLATES X., XI., XII.

Plate X.

A Gnomonogram of Quartz, giving most of the recognised forms. "Dana's Symbols." By J. G. Goodchild.

Plate XI.

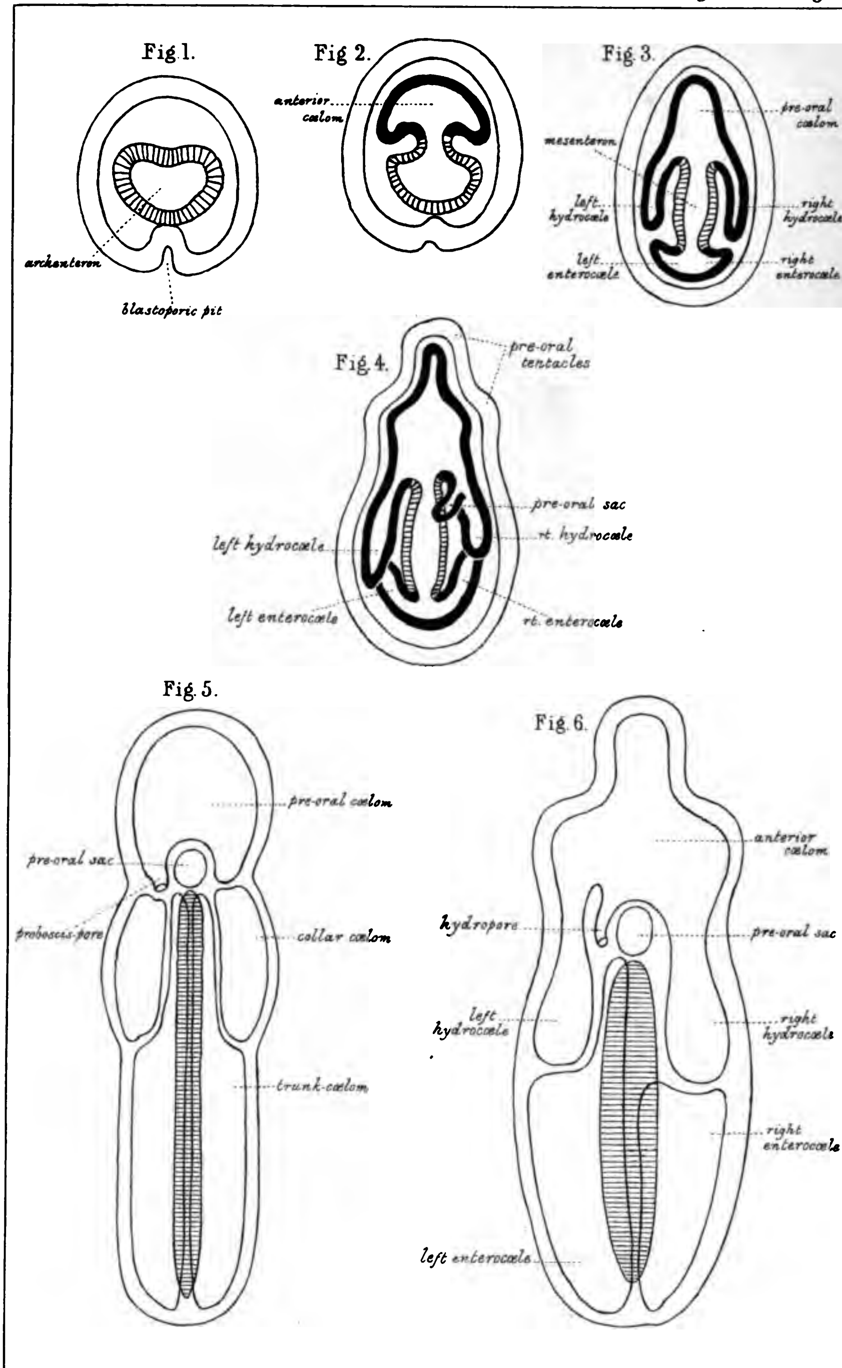
A Stereogram of Barytes; *c*, Projection; giving most of the forms yet described, and some that are new. "Dana's Symbols." By Wilbert Goodchild.

Plate XII.

Stereograms of Orthoclase; *b* and *c*, Projections. "Dana's Symbols." By J. G. Goodchild.

PLATE IX.

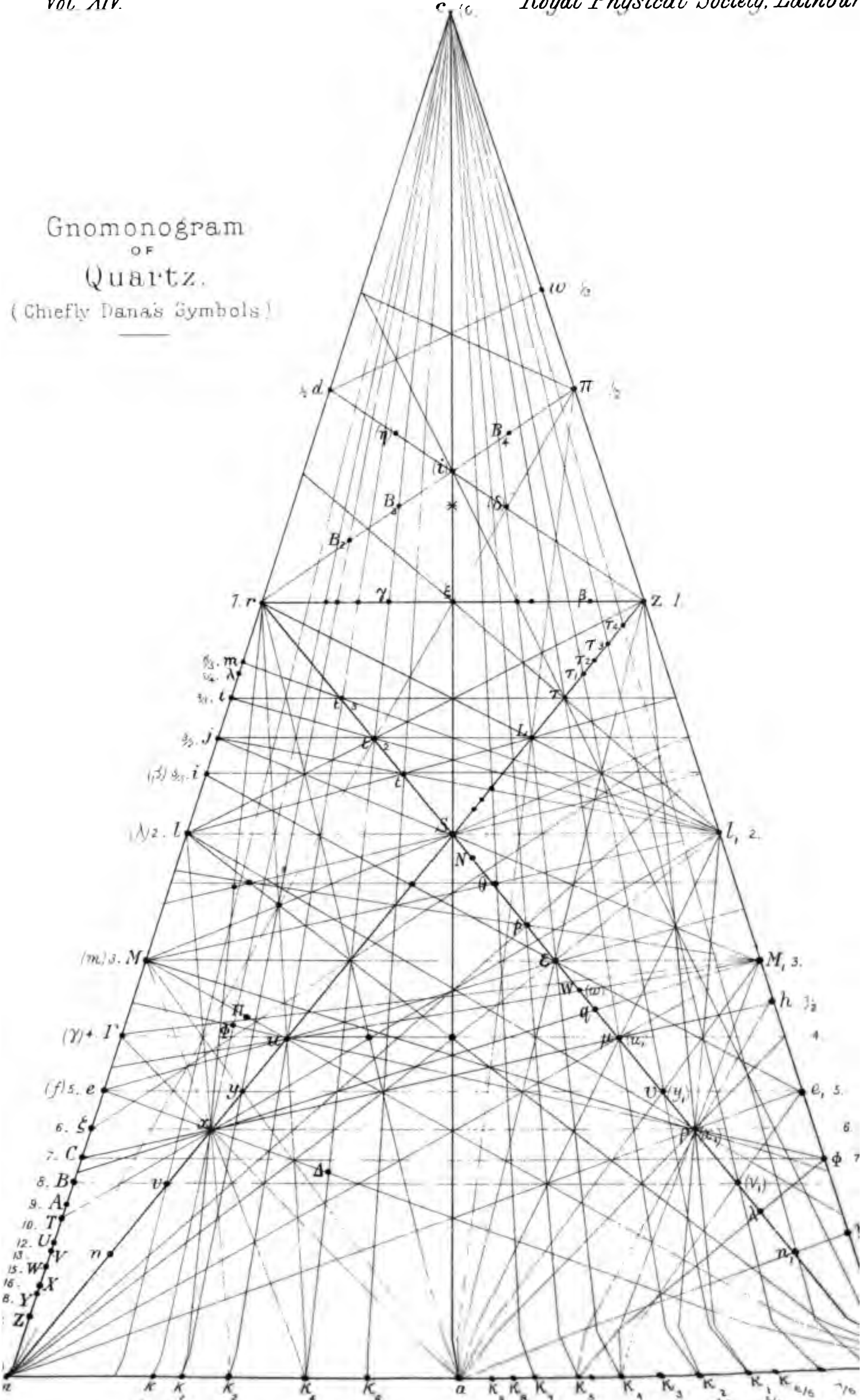
Vol. XIV *Royal Physical Society Edinburgh.*



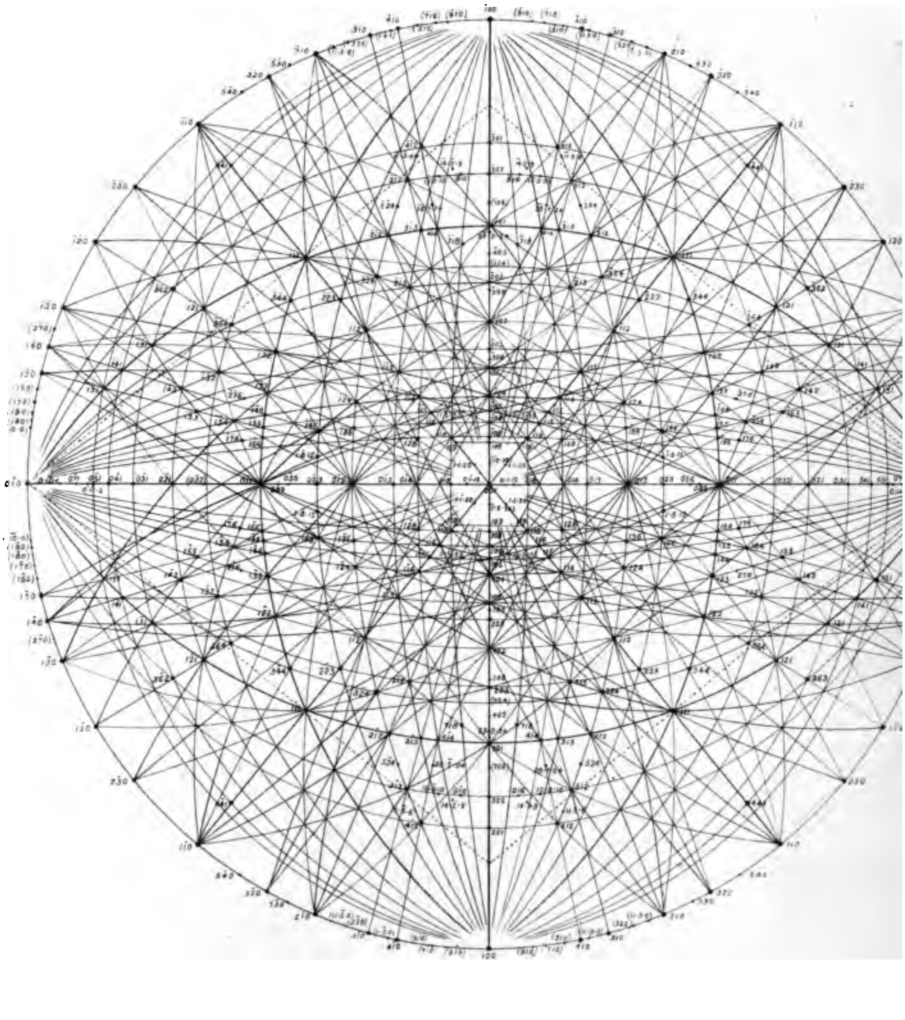
M'Farlane & Erskine, Lith. Edin^r

Gnomonogram OF Quartz.

(Chiefly Dana's Symbols)

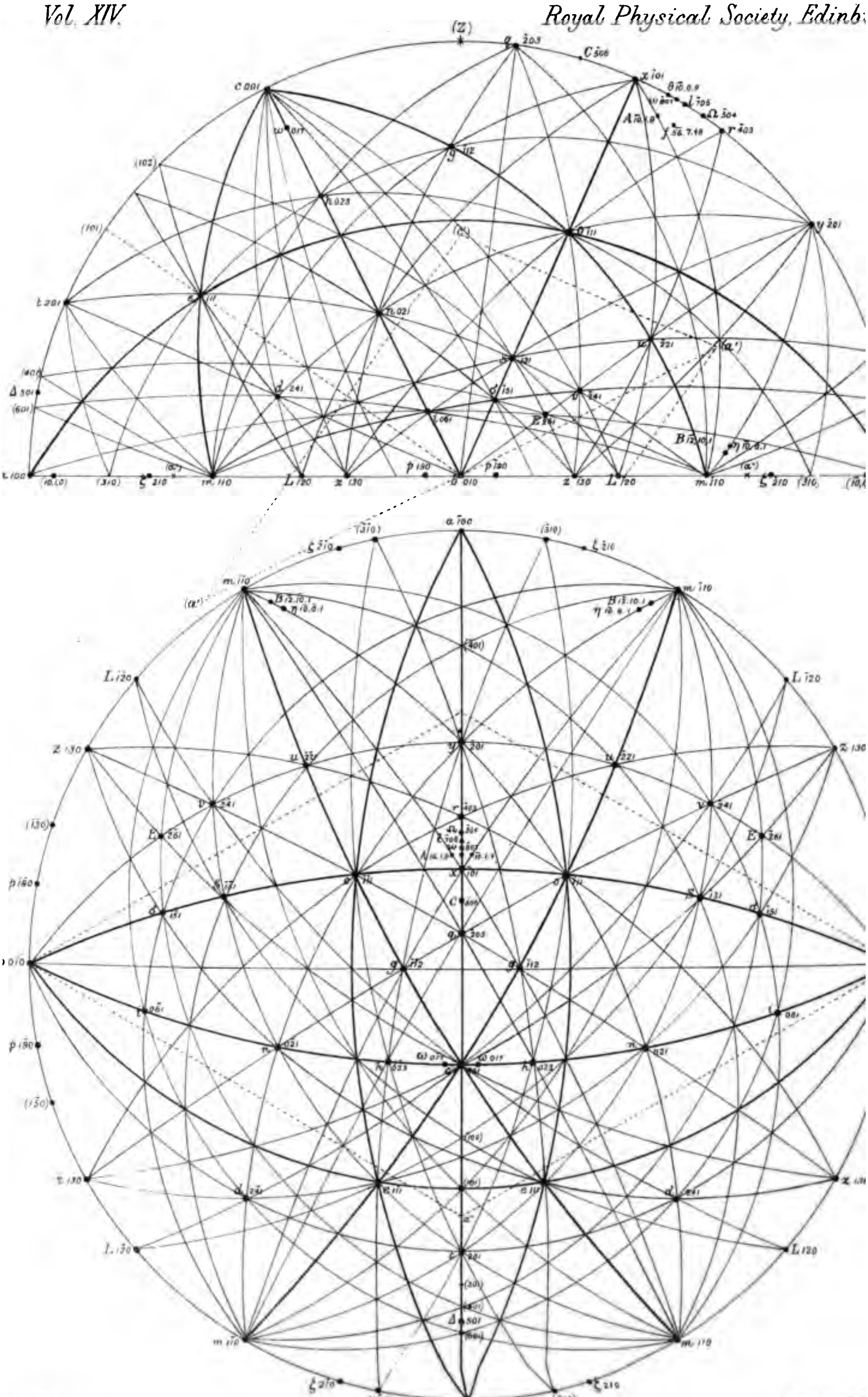


(by permission of … Mineralogy of Scotland")



Barytes.

(by permission of Alex. Thoms Esq., and the Publishers of "Mineralogy of Scotland.")



J. G. Goodchild M'Farlane &

PROCEEDINGS

OF THE

ROYAL PHYSICAL SOCIETY.

SESSION CXXX.

Wednesday, 21*st November* 1900.—B. N. PEACH, Esq., F.R.S., President, in the Chair.

The President delivered the Opening Address, entitled "Scottish Palæontology during the last Twenty Years."

My retirement from the Presidentship of the Royal Physical Society on the threshold of a new century, furnishes a favourable opportunity for reviewing some of the work done in Scottish palæontology during the last twenty years.

In the first case, I shall attempt to treat the work from the biological side; and in the second, I shall try to show the bearing of these discoveries in palæontology upon the geology of Scotland.

PART I.

In treating of the biological aspect of these discoveries, I purpose to begin with the more lowly forms of life and proceed towards the higher. As Mr Kidston has already so exhaustively treated of the fossil plants in his retiring address to our Society, no farther back than the year 1893,[1] I shall proceed at once to the animals.

[1] R. Kidston, *Proc. Roy. Phys. Soc.*, vol. xii. pp. 183-257, 1894.

RHIZOPODA.

Among the Rhizopoda, Nicholson and Etheridge have noted the occurrence of *Saccamina Carteri* in the Stinchar limestone of Girvan, which is of Upper Llandeilo age, and the observation is confirmed in a note by the late H. B. Brady.[1]

A widespread deposit of Radiolarian Chert, occupying a definite geological horizon between the Middle Arenig and the Upper Llandeilo groups, was met with by the Geological Survey during the revision of the Silurian rocks of the Southern Uplands of Scotland, in the years 1888 and 1889. Rounded bodies were detected in the cherts in the field by myself, and these were subsequently determined, by the late Professor H. A. Nicholson and Dr G. J. Hinde, to be the remains of Radiolaria. A suite of specimens was then sent to Dr Hinde in 1890, who published the results of their examination in the *Annals and Magazine of Natural History.* He described twenty-two species of Radiolaria new to science, which range themselves under twelve genera. Of these, six new genera required to be made to receive certain forms, while the rest belong to genera still living, which had already been named by Hæckel, Ehrenberg, and Meyen.[2]

These six genera, like the Foraminiferal genus *Saccamina* above mentioned, are thus shown to range from Lower Silurian time to the present day; but this is what might be expected to occur with such lowly and undifferentiated organisms. According to Barrois, Radiolaria are the oldest known animal organisms, since *Spumularia* (Monosphæroidæ) occur plentifully in the bituminous quartzites of Bretagne, interbedded with pre-Cambrian gneiss.[3]

PORIFERA.

The chief work done among Scottish Fossil Sponges, during the period in review, is by Dr G. J. Hinde. In 1883 appeared his "Catalogue of the Fossil Sponges of the British

[1] "Mon. Girvan Silurian Fossils," pp. 21, 24, 1880.

[2] *Ann. and Mag. Nat. Hist.*, vol. vi. p. 40, 1890.

[3] Eastman's translation of "Zittel's Palæontology," p. 39, 1900.

Museum." In his "Monograph on British Fossil Sponges,"[1] he classifies the work already done by Nicholson and Etheridge, and Messrs Young and Young, and makes plentiful use of material from the Carboniferous rocks of Fife and the west of Scotland, collected by the late James Bennie, the late Dr John Young, John Smith, and the late Dr Hunter-Selkirk, as well as from the older rocks by Professor Lapworth and the late H. A. Nicholson. He describes three species belonging to as many genera of Monactinellida, three species coming under two genera of Tetractinellida, four species ranged under four genera of Lithistida, five species belonging to four genera of Hexactinellida, and one species of Calcispongida.

During the progress of the Geological Survey in the north-west Highlands, specimens of fossil sponges were obtained from the Durness Limestone, and placed along with the genera *Archæocyathus* and *Calathium* of Billings, from the close resemblance to his *Archæocyathus minganensis.*[2]

In 1889 Dr Hinde made use of these specimens for his paper on *Archæocyathus minganensis* of Billings, which he showed did not belong to *Archæocyathus,* but must be considered as a Lithistid sponge, to which he gave the generic name of *Archæoscyphia.*[3]

Several species of *Archæoscyphia, Calathium,* and other sponges have also been discovered in the Cambrian limestones of Skye.[4]

RHABDOPHORA.

A few new species of Graptolites have been described by Miss Elles from Scottish material. Among these may be mentioned *Cephalograptus petalum,* Elles, and *Petalograptus minor,* Elles.[5] The geological significance of the finding of the Graptolites of the Arenig zone, near Ballantrae, by

[1] "Mon. Brit. Foss. Sponges," *Palæontogr. Soc.*, 1887-88.
[2] *Quart. Jour. Geol. Soc.*, vol. i. p. 401, 1888.
[3] *Quart. Jour. Geol. Soc.*, vol. xlv. p. 125, 1889.
[4] *Mem. Geol. Sur.*, "Summary of Progress, 1898," p. 55, 1899.
[5] *Quart. Jour. Geol. Soc.*, vol. liii. p. 186.

Professor Lapworth, will be treated of in the second portion of this address.

ECHINODERMATA.

In 1886 the "Catalogue of the Blastoidea of the British Museum," by R. Etheridge, jun., and P. H. Carpenter, was published.[1] In it, is figured and described *Actinocrinus Bennei*, a Carboniferous species named by R. Etheridge in 1876, after the finder, our late fellow, Mr James Bennie.[2] This is one of many discoveries by which his name is linked with palæontology.

One of the most interesting discoveries of Echinoderm remains recorded from the Palæozoic rocks during the period under consideration is that of plates, wheels, and anchors of holothurideans from the Carboniferous Limestone rocks of Scotland, by the late Mr Bennie, described by R. Etheridge, jun. Mr Etheridge provisionally ascribes the plates to species of the genus *Chirodota* and *Achistrum*. This is the first record of remains of this group having been obtained from Palæozoic strata.[3]

ANNELIDA.

In a series of papers published in the *Geological Magazine* for 1880, R. Etheridge, jun., adds greatly to our knowledge of Scottish Carboniferous tubicolar annelides.[4] For this purpose he avails himself of materials from the Carboniferous rocks of Scotland, especially from the Calciferous Sandstone and the Carboniferous Limestone groups of Fife and the Lothians, from the collections of the Geological Survey, the late Mr C. W. Peach, and the late Mr James Bennie.

He reviews the genus *Spirorbis*, and breaks it up into two sets, *Spirorbis* and *Microconchus*. Of nine species from Scotland, three are new. He also reviews the genus *Serpulites*, Macleay, and describes three species, two of which are new.

[1] "Catalogue of the Blastoidea in the Geol. Dept. of the Brit. Museum," 1886, pp. 308, 310.

[2] *Quart. Jour. Geol. Soc.*, vol. xxxii. p. 103.

[3] *Proc. Roy. Phys. Soc. Edin.*, vol. vi. pp. 183-198, 1880.

[4] *Geol. Mag.*, new ser., decade 2, vol. vii. pp. 109, 171, 215, 258, 304, 362, 1880.

To the genus *Ditrupa*, Berkeley, he adds a new species, and figures *Ortonia carbonaria* and an undetermined species of *Vermilia*.

BRACHIOPODA.

The most important publication dealing with Scottish Brachiopoda is the late T. Davidson's Supplement to his great monograph, published in 1884, which deals with a great amount of material from the Scottish Silurian rocks, especially from the Gray collection and that of the Geological Survey.[1] In his presidential address to this Society in 1881, Mr Etheridge estimates the then known species of Brachiopods from Scottish Silurian rocks at 53.[2] Mrs Gray's list, published in the Appendix to volume i. of the *Memoirs of the Geological Survey of the United Kingdom*, enumerates 120 species from the Girvan region alone.[3] The list given in the same volume by the Geological Survey from the whole of Scotland amounts to 140 species.[4] These great additions to Etheridge's lists are mainly due to the fact that most of the Silurian Brachiopods in the collection of the Geological Survey of Scotland had been examined by Mr T. Davidson during his later years. An interesting point in the work of the Geological Survey, is the finding of species of *Paterina* and *Obolella* in the Cambrian and Arenig rocks of the north-west Highlands and Lanarkshire. All recent Brachiopods pass through the stage of *Paterina*, and some through an *Obolella* stage, during development, and it is a suggestive fact that adult forms with these embryonic characters should be found in the oldest rocks from which Brachiopod remains have as yet been dug up.

LAMELLIBRANCHIATA.

The decade prior to 1880 was one of great activity in the description and classification of Scottish Palæozoic Lamellibranchs, chiefly owing to the energy of Robert Etheridge,

[1] "Mon. Brit. Foss. Brach.," *Palæontogr. Soc.*, vol. v., 1882-1884.

[2] *Proc. Roy. Phys. Soc. Edin.*, vol. vii. p. 27, 1881.

[3] *Mem. Geol. Sur.*. "The Silurian Rocks of Britain," vol. i. pp. 686-697, 1900.

[4] *Ibid.*, pp. 675-679.

jun. Since his departure for Australia, the work has been taken up by Dr Wheelton Hind, who, in the preparation of his monographs on the Carboniferous Lamellibranchs, has largely used the material of the magnificent collections of Mr Neilson and other Glasgow geologists, as well as that of the Geological Survey.[1]

During the progress of the Geological Survey from 1883 to 1885, and again in 1898, a considerable number of bivalves were obtained from the Durness Limestone, which is of Upper Cambrian age. These belong to the genus *Euchasma*,[2] Billings, *E. Blumenbachii* being the only species, and hitherto only known to occur in Newfoundland and Canada. The Scottish specimens evidently belong to several species, and there are several forms which seem to connect the genus with the genus *Eopteria* of Billings.[3] The genus *Euchasma* is placed by Dr William Dale among the Cardiolidæ.[4] In Etheridge's address above mentioned he enumerates 12 species of Lamellibranchs[5] from the Silurian rocks of Girvan, while Mrs Gray's list shows 26 species from the same rocks.[6]

GASTEROPODA.

The chief work among Scottish Palæozoic Gasteropods has been done by Miss Jane Donald, and published in a series of papers in the *Quarterly Journal of the Geological Society* from 1887 to 1898.[7] In these papers she deals chiefly with the genus *Murchisonia*, d'Arch. et de Vern., dividing it up into several subsections. She makes a new species and two varieties of the subgenus *Ectomaria*, adds two new species to *Hormotoma* from the Durness Limestone and the Silurian

[1] "Mon. on Carbonicola, Anthracomya, and Naiadites," *Palæontogr. Soc.*, pt. i., 1894; pt. ii., 1895; pt. iii., 1896. "Mon. on Carboniferous Lamellibranchiata," *Palæontogr. Soc.*, pt. i., 1896; pt. ii., 1897; pt. iii., 1898.

[2] *Canad. Palæoz. Foss.*, vol. i. p. 360, 1861-1865.

[3] *Canad. Palæoz. Foss.*, vol. i. p. 221, 1861-1865.

[4] Eastman's translation of "Zittel's Palæontology," p. 85, 1898.

[5] *Proc. Roy. Phys. Soc. Edin.*, vol. vii. p. 27, 1881.

[6] *Mem. Geol. Sur.*, "The Sil. Rocks of Britain," vol. i. pp. 686-697, 1900.

[7] *Quart. Jour. Geol. Soc.*, vol. xlv. pp. 620-656, 1899; vol. xlviii. pp. 562-575, 1892; vol. liv. pp. 4-72 and 251-272, 1898.

rocks of Girvan. From the Lower Carboniferous rocks she makes fourteen new species of *Murchisonia* (proper), ten new species of the genus *Aclisina*, de Koninck, and makes a new genus *Rhabdospira*, with one species. In addition to fossils gathered by herself, she has taken advantage of the collections of Mrs Gray, Professor Lapworth, John Smith, the late James Bennie, R. Neilson, the late Dr Hunter-Selkirk, the late J. Thomson, Prof. J. Young, the late Dr J. Young, and also that of the Geological Survey.

A comparison of Mrs Gray's list of Silurian Fossils from Girvan[1] shows that the species of Gasteropods numbers 50, while the number given by Etheridge in his address is 28.[2] This addition is greatly due to the publication in 1881 of the late Professor G. Lindström's "Monograph on the Silurian Gasteropods and Pteropods of Gothland,"[3] which has allowed Mrs Gray to determine many of the fossils in her collection. This splendid monograph is certain to have a considerable influence in the determination and classification of the Gasteropods of our Scottish rocks.

During the progress of the Geological Survey in Durness and Skye, a considerable number of Gasteropod remains were collected from the Durness Limestone, in addition to those enumerated in Mr Etheridge's address, who only records eight species.[4] More than that number of species of the genus *Murchisonia* alone occur in the collection, and several American forms of the peculiar genera *Maclurea* and *Ophileta* are represented.[5]

PTEROPODA.

There is a growing feeling amongst palæontologists that the Palæozoic fossils that have been classed with the Pteropoda do not really belong to that order. As yet, no true Pteropod remains have been obtained from strata older than the Cretaceous. There is therefore great difficulty in

[1] *Mem. Geol. Sur.*, "The Sil. Rocks of Brit.," vol. i. pp. 686-697, 1900.

[2] *Proc. Roy. Phys. Soc. Edin.*, vol. vii. p. 27, 1881.

[3] *Kon. Svenska. Vetensk. Akad. Handl.*, Bd. xxx., 1881.

[4] *Proc. Roy. Phys. Soc. Edin.*, vol. vii. p. 27, 1881.

[5] *Mem. Geol. Sur.*, "Summary of Progress for 1898," p. 55, 1899.

knowing where to place these organisms. Many of them are certainly not Pteropods. Some are more probably worms, and some of those with lids, such as *Hyolithus*, may even be extreme forms of hingeless Brachiopods. Two other species of *Salterella*, besides the well-known *S. Maccullochii*, Salter, occur in the Durness Limestone, while several species of *Hyolithus* have been found along with *Olenellus* in the Fucoid beds in several localities in the north-west Highlands. Mrs Gray records several species of *Hyolithus* from the Silurian rocks of Girvan.[1]

CEPHALOPODA.

The chief work among Scottish Palæozoic Cephalopoda has been in the classification of old material. The Rev. J. F. Blake, in his Monograph published in 1882,[2] describes, from the Gray collection of Silurian Cephalopods from the Girvan region, one new species of each of the following genera:—*Orthoceras*, *Cyrtoceras*, and *Gomphoceras;* and three new species of *Orthoceras* from the Silurian rocks for the Geological Survey collection. Of Cambrian forms from the Durness Limestone, he adopts the *Orthoceras mendax*, Salter, and makes two species—*O. durinum* and *O. pertinens.* He looks on *Piloceras* as a genus not sufficiently established. H. H. Foord makes use of Scottish material for his British Museum Catalogue published in 1888.[3] He accepts the *Piloceras invaginatum* of Salter, and shows, from specimens belonging to the Geological Survey of Scotland, obtained during the progress of the Geological Survey in Durness in 1881-82, the relation of the siphuncle to the septa and body-walls, as well as the arrangement of the invaginating sheaths of the siphuncle. He considers the *Orthoceras mendax*, Salter, from peculiarities of the siphuncle, to belong to the genus *Actinoceras.* In the Geological collection from the Durness Limestone, as well as the siphuncles of several

[1] *Mem. Geol. Sur.*, "The Silurian Rocks of Britain," vol. i. pp. 686-697, 1900.

[2] "Mon. of Brit. Foss. Ceph.," part i., 1882.

[3] "Cat. of the Foss. Ceph. in the Brit. Mus.," part i., 1888; part ii., 1891; part iii., Foord and Craik, 1897.

species of *Endoceras*, there are the siphuncles of at least four different species of *Piloceras*.[1]

PHYLLOCARIDA.

The study of Scottish Palæozoic fossils of this group has been actively pursued in recent years. In the years 1880 and 1882 I described three species of Phyllocarid Crustaceans from the Lower Carboniferous rocks of Eskdale, Dumfriesshire, and made the genus *Acanthocaris* to hold them. They are nearly allied to *Ceratiocaris*, Salter, but they differ from it in the great size of the segmented body compared with the carapace, and in the diminutive lateral cercopods of the tail apparatus.[2] The chief systematic work, however, has been done by Professor T. Rupert Jones and Dr Henry Woodward. In a series of articles in the *Geological Magazine*, extending from 1884 to 1892, and in their Reports to the British Association from 1885 to 1895, they make free use of Scottish material. Their work, however, is brought to a focus in their Monograph published by the Palæontographical Society.[3] In it they describe, from the Silurian rocks of Scotland, two new species of *Aptychopsis*, three new species of *Ceratiocaris*, and figure about ten already known species of *Ceratiocaris*, two species of *Discinocaris*, and one of *Peltocaris*. They make a new genus *Calyptocaris* to contain the *Dithyrocaris striata* of Woodward and Etheridge, jun., from the Ludlow rocks of Carmichael Burn in Lanarkshire,[4] and they figure six species of *Dithyrocaris* from the Carboniferous rocks of Scotland.

The number of genera and species of Phyllocarida recorded from Scottish Silurian rocks by the Geological Survey is as follows:—*Aptychopsis*, nine species; *Calyptocaris*, one species; *Caryocaris*, one species; *Ceratiocaris*, ten species;

[1] *Mem. Geol. Sur.*, "Summary of Progress for 1898," p. 55, 1899.

[2] *Trans. Roy. Soc. Edin.*, vol. xxx. pp. 73, 512.

[3] "Mon. Brit. Palæo. Phyllop. (Phyllocarida)," *Palæontogr. Soc.*, part i., 1888; part ii., 1892; part iii., 1898; part iv., 1899.

[4] *Mem. Geol. Sur.*, Explan. Sheet 23, Scotland, Appendix, pp. 49, 57, 100, 1873.

Discinocaris, two species; *Peltocaris*, one species; and *Pinnocaris*, one species.[1]

The occurrence of such an array of Nebalid forms in the uppermost Silurian rocks is a very significant fact, when, as will be shown, the remains of Schizopods and forms intermediate between Schizopods and other existing groups of higher Crustacea are equally abundant in our Lower Carboniferous strata, the next formation in Scotland in the order of time that can with certainty be looked on as marine, the Old Red Sandstone being considered by several eminent geologists to have been deposited in land-locked basins.

SCHIZOPODA.

Prior to the period in review, the Scottish Carboniferous rocks had yielded several forms of the higher Crustacea. The genus *Anthrapalæmon* was made by Salter in 1856[2] to contain two species of prawn-like forms from the Coal-Measures of Lanarkshire, and *Palæocrangon socialis*[3] was the name given by Salter to a shrimp-like animal obtained by the late Rev. D. Brown from the Calciferous Sandstone at Ardross, on the coast of Fife.[4] Salter considered these to be Decapods. Huxley made the genus *Pygocephalus* to hold a peculiar Crustacean, with wide sternites to the trunk, and other Schizopod characters, which he placed in that order.[5] A third species of *Anthrapalæmon* was made in 1877 by R. Etheridge, jun., from specimens obtained by the late J. Bennie from Lower Carboniferous rocks near Dunbar; and a fourth species, *A. Macconochii*, was afterwards added from carapaces got by Mr Macconochie from the Calciferous Sandstone group of Liddesdale.

While working in Eskdale in 1879 and 1880, Mr Macconochie discovered the now famous "Scorpion bed" in the Lower Carboniferous shales at Glencartholm, near Langholm, from which he obtained a large suite of the remains of higher Crustacea. He also gathered Crustacean

[1] *Mem. Geol. Sur.*, "The Silurian Rocks of Britain," p. 671, 1899.
[2] *Quart. Jour. Geol. Soc.*, vol. xvii. p. 528, 1861. [3] *Ibid.*, p. 53.
[4] *Trans. Roy. Soc. Edin.*, vol. xxii. p. 394.
[5] *Quart. Jour. Geol. Soc.*, vol. xiii. p. 363, 1857.

remains from the Lower Carboniferous rocks of Liddesdale and Berwickshire. These were partly described by me in the papers before the Royal Society of Edinburgh in 1880 and 1882, and published in their *Transactions.*[1] In these papers four new species of *Anthrapalæmon* and two new species of *Palæocrangon* were described, a new genus *Pseudogalathea* was formed to hold the *A. Macconochii* of Etheridge, to which another species was added, and all were assigned by me to the Decapoda. A form showing mixed Schizopod characters was considered to belong to the genus *Palæocaris,* Meek and Worthen, and named *P. scoticus.*

From subsequent study of the old material, as well as of many hundreds of new specimens, gathered by Messrs A. Macconochie and J. Rhodes from the Lower Carboniferous rocks of the Scottish and English borders, by Mr Wm. Anderson, from Ardross, and by Mr Paton, from East Kilbride, I have been compelled to modify my views regarding the systematic place assigned to many of the forms. In this change I have been greatly influenced by the study of the Report of G. O. Sars upon the Schizopoda gathered by H.M.S. "Challenger" during its famous voyage.

In the genus *Anthrapalæmon,* I found that underneath the portion of the trunk covered by the carapace there are seven or eight pairs of biramose limbs, the endopodites of which end in a simple claw, and none of which are specially modified for prehension nor act as maxillipedes, while the exopodites are in the form of a many-jointed lash. These limbs are attached to very wide sternal plates, as in *Pygocephalus* and the recent Lophogastrids. The carapaces are generally keeled in the same manner as in *Gnathophausia,* and the telson ends in a similar expansion to that found in that genus. *Pseudogalathea* agrees with *Anthrapalæmon* in all these respects, and must find a place with it. Both appear to me to be ancient forms of Lophogastrid Schizopods. Huxley's *Pygocephalus* will also have to be classed with the same group.

Anthrapalæmon Parki, Peach, is not an *Anthrapalæmon* at all. Though in all respects a Schizopod, it has assumed

[1] *Trans. Roy. Soc. Edin.*, vol. xxx. pp. 73, 512, 1883.

strong Squilla-like characters, and forms the centre of a new family group of Stomatopoda, there being evidently several undescribed species in the collection. *Anthrapalæmon Traquairii*, Peach, is partly founded on a specimen belonging to the above Squilla-like family, and partly on a specimen showing strong Thysanopod characters.

From the study of material presented to the Geological Survey by Mr Wm. Anderson, collected by him from the bed at Ardross from which the Rev. D. Brown obtained the original specimens, *Crangopsis* (*Palæocrangon*) *socialis*, Salter, appears to have all the characters of a Thysanopod, and must be placed under the Euphausiidæ. Several other forms belonging to the Euphausiidæ also occur in the Geological Survey collection of Carboniferous Crustacea, and it seems to me that it is from this branch that the Decapoda descend, but I have not met with the remains of a single true Decapod. *Palæocaris*, as already indicated, is a transitional form between the Schizopoda and Isopoda or Amphipoda. In 1896, W. T. Calman read a paper before the Royal Society of Edinburgh on a recent Crustacean found in a fresh-water lake in Tasmania, which he named *Anaspides*, as it has all its body segments free, and bears no carapace, and though being most nearly allied to the Schizopods has affinity with the Amphipods. It combines many of the characters of *Palæocaris*, Meek and Worthen, and *Gampsonyx*, Jordan, a genus of Crustacea found in the permo-Carboniferous rocks of Saarbrück.[1] Kingsley puts *Pygocephalus* and *Crangopsis* (*Palæocrangon*), Salter, among the Schizopods, and he considers that *Anthrapalæmon* and *Pseudogalathea* are more nearly allied to the Schizopods than to any other forms, an opinion with which I heartily agree.[2]

From the occurrence of so many transitional forms in the Lower Carboniferous rocks, it would appear that the Schizopods were dominant in Carboniferous times, and that they were giving off several branches, the Isopods on one side, the Decapods on another, and the Stomatopods on a third line

[1] W. T. Calman "On the Genus *Anaspides*," *Trans. Roy. Soc. Edin.*, vol. xxxviii., 1896.

[2] Eastman's translation of "Zittel's Palæontology," p. 659, 1900.

of divergence. The Lophogastrids seem to have reached their limit, and the present forms are preserved through having taken to deep water, while the Thysanopods have for the most part become pelagic. *Anaspides* may be looked upon as a *Palæocaris*-like form, which has been preserved by taking to a fresh-water habitat, while all its marine relatives perished in the more severe struggle for existence which marine forms have to undergo.

MEROSTOMATA.

The most important additions to the knowledge of Scottish Eurypterids since the publication of Woodward's "Monograph on the Merostomata" by the Palætographical Society, has been made by Malcolm Laurie, who has described, in a series of papers before the British Association and the Royal Society of Edinburgh, between the years 1892 and 1899, the collections made by the late Messrs Henderson, Hardie, and himself from the Wenlock Rocks of the Gutterford Burn, in the Pentland Hills.[1] The collections of Messrs Henderson and Hardie are now in the Museum of Science and Art, Edinburgh.

In his papers before the Royal Society of Edinburgh he adds four new species to the genus *Eurypterus*, Dekay, three species to *Stylonurus*, Page, and makes a new species of *Slimonia*, Page. He is compelled to make two new genera to receive some more generalised forms. One of these, *Drepanopterus*, comprising three species, combines characters found in *Stylonurus* and *Eurypterus*, and for one species with very generalised characters he makes the genus *Bembicosoma*.

The deposit in which the above forms occur, as shown by the evidence afforded by Graptolites, is of Wenlock age, and consequently older than the Ludlow rocks of Lesmahagow, from which most of the other described Scottish Silurian Eurypterids have been obtained. The discovery of more primitive forms, combining the characters of more than one

[1] *Rep. Brit. Assoc.*, p. 729, 1892; *Trans. Roy. Soc. Edin.*, vol. xxxviii. part i. p. 151, 1893; *Ibid.*, vol. xxxix. p. 575, 1890.

genus in the older rocks, therefore gives strong support to the doctrine of "descent with modification." As to the importance of the find, it may be as well to quote Professor Laurie's own words, viz.: "Looking at the fauna of this bed as a whole, it may safely be said to have yielded more information of importance and interest concerning these fossil Arthropoda than any other single deposit."[1]

ARACHNIDA.

The first record of a Scottish Palæozoic Scorpion is by Dr Henry Woodward in a paper before the Geological Society in 1873, when he describes a doubtful tail segment of *Eoscorpius* from the Lower Carboniferous rocks of Carluke. In 1882 a paper was read by me before the Royal Society of Edinburgh, in which three new species of *Eoscorpius* were described from the Geological Survey collections made by Mr A. Macconochie from the Lower Carboniferous rocks at the famous locality of Glencartholm, near Langholm, and by the late Mr James Bennie in the Coal-Measures of Fife.[2] Up to that time these were the oldest known Arachnida; but in 1884 Lindström announced the discovery of a Fossil Scorpion from the Upper Silurian (Ludlow) rocks of Gothland, which was afterwards described by Thorell and him under the name of *Palæophonus nuncius*.[3] It was truly a messenger, for immediately on the announcement of its discovery the late Dr Hunter-Selkirk produced a species of *Palæophonus* which was found in the Upper Silurian (Ludlow) rocks of the Logan Water, near Lesmahagow, in 1883, which he named *P. caledonicus*.[4] This was soon followed by the announcement of an American Silurian Scorpion, *Proscorpius Osborni*, by R. P. Whitfield, from near the top of the Upper Silurian rocks.[5] The chief characteristics of all these Silurian Scorpions is the large size and forward position of the ocelli,

[1] *Mem. Geol. Sur.*, "The Sil. Rocks of Britain," p. 595, 1899.

[2] *Trans. Roy. Soc. Edin.*, vol. xxx. pp. 397-412, 1883.

[3] T. Thorell and G. Lindström, "On a Silurian Scorpion from Gothland," *Kon. Svenska. Vetensk. Akad. Handl.*, Bd. xxi. No. 9, 1885.

[4] *Nature*, vol. xxxi. p. 295, 1884.

[5] *Science*, vol. vi. p. 87, 1885.

the large chelicerae, and the fact that the walking limbs are tipped with only a single claw.

In 1889, while working out the collection of Merostomata from the Wenlock rocks of the Gutterford Burn in the Museum of Science and Art, Malcolm Laurie discovered the remains of a Scorpion, which he described under the name of *Palæophonus loudonensis*.[1] This species, from a lower horizon than any other yet discovered, agrees in most respects with the characters of all the other Silurian forms; but Professor Laurie observed indications of curious plate-like appendages on the ventral surfaces of the mesosomatic segments, suggesting that either they were gills or that "gill-bearing appendages had not become completely fused with the abdomen to form an air-chamber, as in recent forms."[2]

With regard to the Carboniferous Scorpions, that which strikes the observer is their extreme likeness to modern ones, the chief difference being in the larger size and more forward position of the central eyes, and also the relatively longer size of the pentagonal sternal plate in the older forms. Indeed, there seems to be greater differences among some recent species themselves than there is between some modern Scorpions and the Carboniferous ones. This is, perhaps, not so very astonishing when we consider that the Scorpions are the most generalised and most archaic form of living Arachnids.

MYRIAPODA.

Up to the time when I brought before our Society a paper on *Kampecaris* and *Archidesmus*, from the Lower Old Red Sandstone of Forfarshire, and which is published in our *Proceedings* for 1882, the oldest known Myriapods were from the Carboniferous formation,[3]—two species of Chilognathous Myriapod, which differ from all recent and known fossil forms in having the tergal and sternal elements of each segment free from those of neighbouring segments, so that each body-ring bore only a single pair of limbs. For one

[1] *Trans. Roy. Soc. Edin.*, vol. xxxix. p. 375, 1899.
[2] *Mem. Geol. Sur.*, "The Sil. Rocks of Britain," p. 598.
[3] *Proc. Roy. Phys. Soc. Edin.*, vol. vii. pp. 177, 178, 1882.

form, Page's name of *Kampecaris forfarensis* was retained, but a new genus, *Archidesmus*, had to be erected to hold another species, which was called *A. Macnicoli* after the finder, Mr Walter Macnicol, of Tealing. Scudder afterwards made these forms the type of a family, the Archidesmidæ, which fell under his order of Archipolypodidæ.

In 1898 I made a further communication to our Society, describing a species of *Archidesmus*, *A. Loganensis*, from the collection of the Geological Survey, which was found by Messrs Macconochie and Tait in the Upper Silurian (Ludlow) rock of Logan Water, near Lesmahagow,[1] thus carrying back the history of these old air-breathers a stage farther. In the same paper I described a new genus of Iulus-like form, which I named after the late Mr Paton, who obtained it from the Carboniferous limestone of East Kilbride, and which was acquired by the Museum of Science and Art from the late Mr Coutts of Glasgow, after whom it is specifically named. In the same paper it was found necessary to erect a new genus, *Anthracodesmus*, to contain a form strongly resembling the recent *Polydesmus*, both in outward form and in the pattern of the sculpturing, which was specifically named after A. Macconochie, who collected it from the Calciferous sandstones of Lennel Braes, near Coldstream. A species of *Kampecaris*, *K. obanensis*, was also described from the Lower Old Red Sandstone rocks of Kerrera, near Oban, collected for the Geological Survey by A. Macconochie.

INSECTA.

Although the Scottish Carboniferous rocks have produced Scorpions and Myriapods in considerable abundance, Insect remains are of rare occurrence. In 1887, however, Dr H. Woodward described, under the name of *Etoblättina Peachii*, the remains of an interesting Cockroach, showing characters that are found in the larval stages of its recent congeners. The specimen was found by Mr Sinclair in a nodule in the Coal-Measures, at Kilmaurs, in Ayrshire.[2]

[1] *Proc. Roy. Phys. Soc.*, vol. xiv. pt. i. pp. 113-126, 1899.
[2] *Geol. Mag.*, new ser., dec. iii., vol. iv. p. 432, 1888.

PISCES.

During the last twenty years there has been great activity in Scottish fossil Ichthyology. This is chiefly owing to the great knowledge of the subject by our Secretary, Dr Traquair, who imparts his own energy and enthusiasm to collectors. During the period mentioned he has described no less than 80 new species of fishes from the Palæozoic rocks of Scotland, 54 from the Carboniferous, 18 from the Old Red Sandstone, and 8 from the Silurian rocks.

Prior to 1880, Dr Traquair had published his monograph on the structure and affinities of the Palæoniscidæ,[1] in which he showed that the family was related to the Sturgeons, and not to the Lepidosteidæ. This is now accepted by most writers on the subject. This was followed, in 1879, by his memoir on the structure and affinities of the Platysomidæ,[2] in which he showed that the Platysomidæ are an offshoot from the Palæoniscidæ, and that they had nothing to do with the Pycnodonts nor with the Dapediidæ, the resemblance between them and those two families being due to convergence phenomena alone.

In 1880 he described the Lower Carboniferous Fishes of Eskdale, from the Geological Survey collections, and showed that nearly all the Ganoids belonged to new species, and that many of the genera were also peculiar to the rocks of that area. He described new genera of great interest, among which are *Phanerosteon*, *Canobius*, and *Tarrasius*.[3]

During the period he has described *Cladodus Neilsoni*, a shark with fins of great morphological interest, as well as a specimen of a shark, *Psephodus magnus*, Agassiz, from the Lower Carboniferous rocks of East Kilbride, showing a mouth full of teeth, which had hitherto been assigned to separate fishes, viz., *P. magnus*, *Helodus planus*, and *Helodus didymus*, which were thus shown to belong to one and the same fish.

Dr Traquair has contributed largely to the knowledge of the Asterolepidæ and the Coccosteidæ, as well as to the

[1] *Palæontogr. Soc.*, 1877. [2] *Trans. Roy. Soc. Edin.*, vol. xxx., 1880.
[3] *Trans. Roy. Soc. Edin.*, vol. xxx.

Palæoniscidæ and Platysomidæ. One of his discoveries that has excited attention and interest is that of *Palæospondylus Gunni*, named after its finder, Mr Marcus Gunn, from the Caithness flagstones at Achanarras. Dr Traquair suggests that, from its large single nasal opening, surrounded by cirri and other characters, it may be an ancient Marsipobranch. If this is not its true systematic position, then it is quite impossible to refer it to any other group of existing Vertebrata.

Dr Traquair has also described, from the collection of the Geological Survey obtained by Messrs Macconochie and Tait from the Ludlow and Downtonian rocks of Lanarkshire and Ayrshire, a suite of Fishes till then unknown to science, with the exception of the genus *Thelodus*, the hollow scales of which, mistaken for teeth by Agassiz, had been known to occur in great numbers in the Ludlow "Bone-bed" and in the Upper Silurian rocks of the Baltic. An entire specimen of a problematical fish, from the Lower Old Red Sandstone of Forfarshire, had been in 1870 imperfectly described by Powrie under the name of *Cephalopterus Pagei*, and this was found by Dr Traquair to belong to *Thelodus*, and re-described and figured by him as *Th. Pagei.* From the Geological Survey collection he described two species of *Thelodus.* He instituted the genus *Lanarkia* to contain three species of similar form to *Thelodus*, but having hollow spines instead of scales, and placed both genera in the family of the Cœlolepidæ. For a similarly shaped form, with a strong resemblance to *Cephalaspis*, and having eye orbits similarly placed, but in which the separate ossicles which cover the head-shield are not confluent, he made the genus *Ateleaspis*, which is apparently intermediate between the Cœlolepidæ and the Cephalaspidæ. *Birkenia elegans* is the name of a shapely fish-like form, with the body and tail and back fin reminding us of those of *Cephalaspis*, and a row of hooked ridge scales along its central margin, but which has no head-shield, and in which the head is covered with small scutes. *Lasanius problematicus* and *L. armatus* are regarded as nearly allied to *Birkenia*, having a row of hooked ventral ridge scales, but with no further osseous

armature than a set of eight slender geniculated ossicles on each side behind the head. These two genera he places in his order of Anaspida. According to the view of Dr Traquair, this find of Fossil Fishes which he has described is of very great morphological significance. The order of the Heterostraci, made to hold the Pteraspidæ, must also include the Cœlolepidæ, the Psammosteidæ, and the Drepanaspidæ. He considers that, beginning with the Cœlolepidæ, with shagreen-like plates or spines, there is a progressive specialisation of the dermal armour through the Psammosteidæ to the Pteraspidæ, in which there is a carapace with solid plates. From their shagreen-like armour, he thinks that the Cœlolepidæ were probably derived from some primitive form of Elasmobranch; but of that he is not certain. He also considers that *Ateleaspis* above-mentioned shows a connection between the Heterostraci and the Osteostraci. Dr Traquair's classification is therefore as follows:—Under the subclass Ostracodermi he places the orders Heterostraci, Osteostraci, and Anaspida. As if it were in prophetic anticipation of the above great discoveries, Dr Traquair had already described a species of *Psammosteus*, *P. Taylori*, after the finder, Mr Taylor, of Llanbryde, from the Upper Old Red Sandstone of Morayshire, as well as the *Thelodus* (*Cephalopterus*) *Pagei* above-mentioned, and had procured for the Museum of Science and Art some very fine specimens of *Drepanaspis* from the Lower Devonian of the Hunsrück, in Germany, which placed him in a position the more readily to grasp the significance of his discoveries.

PART II.

As already stated, the second part of this address is devoted to showing the bearing of these discoveries in Palæntology during the last twenty years on the geology of Scotland. For this purpose I shall consider the geological formations in the order of their relative antiquity, beginning with the most ancient and proceeding towards the younger.

No remains of any organism have yet been obtained from the Lewisian rocks in Scotland, but it would be unsafe to infer from this fact that life did not exist within the area during their accumulation. Certain cherts, limestones, and dark graphitic schists, mapped by the officers of the Geological Survey in the Loch Maree district of Ross-shire, probably owe some of their characters to organised matter.

In the Torridonian formation, radiating bodies like gigantic sponge-spicules were met with by the Geological Survey, in shales near Stoer in Sutherlandshire, that were once believed to be of organic origin; but there is more reason to consider that they are purely mineral.

Worm tracks and casts have been met with in several places, especially in the shales of the lowest members of the formation. In 1898 the collectors of the Geological Survey vigorously searched the beds most likely to yield fossils, but with little success, worm tracks only having been found. Certain dark phosphatic nodules were observed, however, in the highest beds of the formation, which occur on the Cailleach Head, near the mouth of Little Loch Broom. Some of these nodules have been microscopically and chemically examined by Mr Teall. Their chemical composition itself was sufficient to make it highly probable that they had an organic origin; and this obtains confirmation from the fact that certain spherical cells and brown coloured fibres, which appear to be the debris of organisms, were observed in them by Mr Teall. These are the first actual organic remains that have, as yet, been recorded from the Torridonian formation in Scotland.[1]

In the year 1891, during the progress of the Geological Survey of West Ross-shire, Messrs J. Horne and A. Macconochie found the head-shields of a trilobite in the Fucoid beds, and Serpulite Grit at Allt Righ Ian and Lochan Nid, in the Dundonnell Forest, south of Ullapool.[2] The trilobite remains proved to belong to a species of *Olenellus* very near to *O. Thomsoni*, the original form found in the Georgian or

[1] *Mem. Geol. Sur.*, "Summary of Progress for 1899," p. 185, 1900.

[2] *Ann. Rep. Geol. Sur.*, 1891, p. 284, 1892.

Lower Cambrian terrane of North America. This discovery fixed the Lower Cambrian[1] age of these strata, which up to that time had been looked upon as Lower Silurian. The discovery was soon followed up by Mr Macconochie, who, in 1894, obtained a suite of fossils from the Fucoid beds on Meall a Ghuibhais, near Kinlochewe, also in Ross-shire, which yielded several species of *Olenellus*, one of which is very near to *O. Gilberti*, the form which characterises the zone in the Western States of America, as well as other fossils of American type.[2] Mr Macconochie afterwards proved the presence of this fauna in these beds from Eriboll in Sutherland to Sleat in Skye. Up to the time of the above-mentioned discoveries, the Durness Limestone was considered to be of Silurian age, in accordance with the determination in 1859, by Salter, of the fossils found at Durness by C. W. Peach.[3] In the same paper Salter also pointed out the American facies of the fossils. The study of the fossils gathered by the Geological Survey from the Durness Limestone in 1883 and 1884 led to the belief that they belong to a lower horizon than that assigned to them by Salter. In 1888 Sir A. Geikie showed, by means of fossil evidence, that a set of marbles that occur in the Strath district of Skye, and which had been looked on as Liassic limestones altered by Tertiary plutonic masses, are really inliers of Durness Limestone.[4] During the progress of the Geological Survey in Skye, further collections of fossils were made from these strata, and in 1899 a list of fossils gathered from these beds appeared in the "Summary of Progress for 1898."[5] The list shows that many of the forms are common to the limestones of Strath and two of the subdivisions of these limestones at Durness, as well as to certain rocks in Newfoundland. In the last-mentioned region the rocks containing these forms have been shown by

[1] "The Olenellus Zone in the N.W. Highlands," *Quart. Jour. Geol. Soc.*, vol. xlviii. p. 227.

[2] *Quart. Jour. Geol. Soc.*, vol. li., 1894.

[3] *Quart. Jour. Geol. Soc.*, vol. xi. pp. 374-381, 1899.

[4] *Quart. Jour. Geol. Soc.*, vol. xliv. p. 62, 1888.

[5] *Mem. Geol. Sur.*, "Summary of Progress for 1898," p. 55, 1899.

Billings to underlie rocks which, at Cow Head and other places, yield such typical Lower Arenig Graptolites as *Phyllograptus*, *Tetragraptus*, *Bryograptus*, and *Callograptus*.[1] It is inferred, therefore, that the underlying rocks represent the top of the Cambrian formation. It follows, therefore, that these zones of the Durness Limestone are probably Upper Cambrian; and in further confirmation of this inference, Messrs Macconochie and Tait last year found, both in Skye and Durness, some trilobite remains of a Middle and Upper Cambrian facies.[2]

It may now be considered that the Durness Limestone probably represents the Middle and Upper Cambrian, and perhaps also the base of the Lower Silurian or Ordovician formations. The Lower Cambrian appears to extend upwards into the first thirty feet of the Durness Limestone, which contains two thin zones crowded with *Salterella rugosa* and *S. pulchella*, fossils of the Olenellus zone.[3] It embraces the Serpulite grit and Fucoid beds, and extends downwards to at least as far as the third subzone of the Upper Quartzite, or "Pipe-rock," Mr Cadell having recorded the occurrence of *Salterella Maccullochii* from that horizon.[4] The underlying zones of the Quartzite, down to the unconformable base-line, having afforded no fossil evidence beyond that of the vertical cylinders of sand ("pipes"), the *Scolithus linearis* of American palæontologists may even be pre-Cambrian in age; but it has been found convenient to retain them in the Cambrian formation till evidence to the contrary is forthcoming.

Although Professor Lapworth's paper on the "Moffat Series"[5] had already laid the basis for the classification of the Silurian rocks entering into the Southern Uplands of Scotland, yet, during the period under consideration, a good deal of work has been done in that direction: thus Professor Lapworth's discovery of *Phyllograptus*, *Tetragraptus*, and

[1] *Geol. Sur. Canada*, "Palæozoic Fossils," Billings, vol. i. pp. 336-376, 1861-65.

[2] *Mem. Geol. Sur.*, "Report of Progress for 1899," p. 186, 1900.

[3] *Quart. Jour. Geol. Soc.*, vol. xliv. p. 408, 1888.

[4] *Ibid.*

[5] *Quart. Jour. Geol. Soc.*, vol. xxxiv. pp. 240-346, 1878.

other Lower and Middle Arenig forms in the black shales of Bennane Head, near Ballantrae, in Ayrshire, established the Arenig age of what were known as the "Ballantrae Rocks."[1] The subsequent work of the Geological Survey confirmed that discovery, and also proved that *Tetragraptus* and an Arenig Phyllopod, *Caryocaris Wrighti*, occur in fine tuffs intercalated with the lowest lava flows exposed along the Ayrshire coast north of Ballantrae, and which are the lowest rocks of the Southern Uplands.[2] It further shows that *Tetragraptus* occurs, along with *Kutorgina*, *Obolella*, and other hingeless Brachiopods, in mud-stones immediately overlying the volcanic rocks, and beneath the zone of Radiolarian Chert in the Abington district of Lanarkshire, proving that Arenig rocks are exposed on the crests of several of the more deeply denuded anticlines right across the Southern Uplands.[3]

The rocks of the Radiolarian Zone already mentioned have not yielded any other remains of life than Radiolaria, of which they are almost entirely composed, with the exception of a few sponge-spicules,[4] and are thus entitled to be looked upon as having been true radiolarian oozes accumulated in a clear, though not necessarily an abyssmal ocean. As no fossils of value for zoning purposes have been obtained from these rocks, their relative age has to be determined by other means. During the progress of the Geological Survey along the Ayrshire coast south of Ballantrae, a band of dark shale was discovered immediately overlying the Radiolarian Chert Zone, which yielded an abundant Graptolite fauna of the *Cœnograptus gracilis* zone, denoting an Upper Llandeilo horizon.[5] It follows, therefore, that the Radiolarian Chert Zone of the south of Scotland, notwithstanding that it is only about 60 feet thick, must represent at least the deposits of Upper Arenig and Lower Llandeilo time.

[1] *Geol. Mag.*, Jan. 1889, part i., "The Ballantrae Rocks."

[2] *Mem. Geol. Sur.*, "The Silurian Rocks of Britain," pp. 435, 439, 440, 1889.

[3] *Ibid.*, pp. 422, 429.

[4] *Ann. and Mag. Nat. Hist.*, vol. vi. p. 40.

[5] *Mem. Geol. Sur.*, "The Silurian Rocks of Britain," pp. 422, 429, 1900.

The area over which the Ballantrae volcanic rocks and the Radiolarian Cherts are known to exist in the Southern Uplands is about 2000 square miles; but during the last few years a narrow strip of rocks containing a volcanic zone, Radiolarian Cherts, and black shales, has been mapped by the officers of the Geological Survey at intervals along the Highland border from near Stonehaven, on the east coast, to the island of Arran. In this belt there is a similar succession and arrangement of these rocks to that of the Ballantrae rocks in the Southern Uplands. They were first differentiated from the Highland schists by Mr Barrow, who mapped their outcrops in Forfar and Kincardine shires.[1] Mr Dakyns,[2] and afterwards Mr Clough, mapped them in extreme detail where they occur in the neighbourhood of Callander and Aberfoyle, in Perthshire and Dumbartonshire,[3] and in 1899 Mr Gunn announced their occurrence in Arran, where they occupy a similar position to that which they hold elsewhere along the Highland border line.[4] The black shales associated with these rocks have not yet afforded any identifiable Graptolites, though they show markings which may have been their remains, but this may be owing to the fact that the rocks are much shattered, cleaved, and even metamorphosed in places. There is a strong presumption, nevertheless, that these rocks are the reappearance of the Ballantrae horizons on the north side of the newer Palæozoic rocks of the central valley of Scotland, in which case the area over which the Ballantrae rocks occur in Scotland alone must be at least 4000 square miles. An even greater development of these peculiar rocks, and doubtless a continuation of the same belt, occurs next to rocks like the Highland schists of Perthshire in County Tyrone, in Ireland, so that the area over which they occur must be very wide.[5] If the identification of the Ballantrae rocks with those of the Highland

[1] *Ann. Rep. Geol. Sur.*, p. 266, 1893.

[2] *Ibid.*, p. 266.

[3] *Ibid.*, 1895, p. 26; 1896, p. 28; *Mem. Geol. Sur.*, "The Silurian Rocks of Britain," pp. 422, 429.

[4] *Mem. Geol. Sur.*, "Summary of Progress for 1899," pp. 66-71, 82.

[5] A. Geikie, "Ancient Volcanoes of Britain," vol. i. p. 240.

border be correct, then these rocks will have a considerable influence in fixing the date of the contortion of the Highland rocks along the Highland border, just as the evidence obtained from the Durness Limestone will have to be considered when dealing with the date of the ridging up and alteration of the rocks in the north-west Highlands. From the nature and distribution of the Durness Limestone and of its fossil contents, it is almost certain that a clear ocean, free from land-borne sediment, existed over what are now the north-west Highlands in late Cambrian and early Silurian (Arenig) time, and if the Highland border rocks are the continuation of those of Ballantrae, then a clear sea, away from land, must have stretched in Arenig times from what are now the Southern Uplands to the Highland border at least, since the Radiolarian Cherts extend over all this area. It is certain that the Durness Limestone is involved with the other rocks of the north-west Highlands in the great movements which have brought about the structure of that region, and in like manner the supposed Ballantrae rocks partake in the extreme folding to which the southern Highland rocks have been subjected; and, as far as Perthshire is concerned, they are in the same state of metamorphism as the adjoining Highland schists.

For our purpose it is necessary to return to the consideration of the newer Silurian rocks of the Southern Uplands. In 1878 Professor Lapworth's epoch-making memoir on the "Moffat Series" made its appearance.[1] In it he proved that the three great divisions of "Siluria" are represented in a condensed form in about 300 feet of strata in the Moffat area. Each division is characterised by a distinct Graptolite Fauna; the Llandeilo by his "Glenkiln," the Caradoc by his "Hartfell," and the Llandovery by his "Birkhill" Group of Graptolites. He further demonstrated that each division is capable of being subdivided into zones characterised by one or more zonal forms of Graptolite. Having placed these facts on an unassailable basis, he made use of the knowledge thus gained to work out the structure of the Girvan area,

[1] *Quart. Jour. Geol. Soc.*, vol. xxxiv. p. 240, 1878.

which, up to that time, had defied the attempts of geologists to unravel. The results of this study appeared in his paper before the Geological Society in 1882.[1] By means of the clue afforded by the Graptolites, he was able to show that his "Barr Series" contained a Glenkiln (Upper Llandeilo) fauna, his "Ardmillan" series a Hartfell (Caradoc) fauna, and his "Newlands" series a Birkhill (Llandovery and Tarrannon) fauna. Viewed in the light of these facts, the apparent anomalies presented by the study of other forms of life, which had hitherto puzzled geologists, disappear, and the fossils of the Girvan region arrange themselves along corresponding lines to those which they do over the rest of Britain and northern Europe. A confirmation of this statement may be made by an appeal to the list of fossils from the Silurian rocks of the Girvan area supplied by Mrs Robert Gray, a monumental list of fossils gathered, either by her own hand or with the help of those of members of her family.[2]

The publication of the paper on the Stockdale Shales of the Lake District of England by Messrs Nicholson and Marr, which appeared in 1888, has had a considerable influence upon Scottish Silurian geology.[3] In that paper they apply the zonal method of mapping to the Tarrannon rocks of the Lake District, which are there represented by a comparatively small thickness of pale shales, but which they show to be capable of subdivision into several life-zones, each characterised by forms of Graptolites. Applying this knowledge to the Scottish rocks, the Geological Survey found that over a wide area in the central and southern parts of the Southern Uplands the grits and shales contain identical forms of Graptolites to those of the Stockdale Shales, but distributed throughout a much greater thickness of coarser strata. This fact is in accordance with the evidence obtained throughout the whole of the Southern Uplands, where, from the distribution of the sediments, the

[1] *Quart. Jour. Geol. Soc.*, vol. xxxviii. p. 537, 1882.

[2] *Mem. Geol. Sur.*, "The Silurian Rocks of Britain," vol. l. pp. 686-697, 1899.

[3] *Quart. Jour. Geol. Soc.*, vol. xliv. p. 654, 1888.

land appears throughout Silurian times to have been persistently towards the north, and the open sea towards the south. Though the detailed structure of the area over which the rocks holding the Graptolites of the Stockdale Shales in Scotland has still to be made out, the Tarrannon age of the rocks distributed over a vast tract of country, stretching from St Abb's Head to the Mull of Galloway, is made certain.

The correlation of the Wenlock Ludlow rocks in Scotland, with their equivalents in England and the rest of Europe, had been accomplished prior to 1880. During the revision of the Upper Silurian rocks in the years 1896, 1897, in the Lesmahagow district of Lanarkshire, Messrs Macconochie and Tait[1] obtained a large suite of Fish remains from rocks which up to that time had been considered as the basement members of the Lower Old Red Sandstone. The Fish Fauna has been shown by Dr Traquair to be very nearly allied to that of the Ludlow "Bone-Bed" of the Welsh border, though differing from it in many respects, and especially in the fact that the Fish are represented in the Bone-Bed by rolled debris only, while in the Lesmahagow bed they are almost entire. This find has led to the correlation of the beds in which they occur with the Downtonian rocks of the Welsh border, and thus forming the highest subdivision of the Silurian system. The index map accompanying volume i. of the *Memoirs of the Geological Survey of the United Kingdom* shows the areas in which the rocks have been transferred from the Lower Old Red Sandstone to the Silurian formation.[2]

Before quitting the subject of the Silurian rocks, we may indicate how fossil evidence can be used to fix the date of an unconformability, and show how a marked break took place within the period of the life of the Glenkiln Graptolite Fauna in the Ballantrae region of Ayrshire. South of Ballantrae, as has been above mentioned (p. 383), a dark shale occurs conformably overlying the Radiolarian Cherts,

[1] *Mem. Geol. Sur.*, "Summary of Progress for 1897," pp. 72-74, 1898.

[2] *Mem. Geol. Sur.*, "The Silurian Rocks of Britain," vol. i. (index map), 1900.

from which a Glenkiln (Upper Llandeilo) suite of Graptolites was obtained by the Geological Survey.[1] North of the Stinchar, the Kirkland and Benan conglomerates, with the Stinchar limestone and Graptolitic mud-stones, lie unconformably on the denuded edges of the Radiolarian Cherts and the Ballantrae igneous rocks, and the conglomerates are made up of the well-rounded fragments of the rocks of both these zones. The Graptolitic mud-stones which are associated with the limestone, as shown by Lapworth, contain several forms of Graptolite belonging to the uppermost Glenkiln zone.[2] The Ballantrae rocks of this region were therefore raised from the bed of a clear sea, converted into a land surface, which was deeply eroded, and which supplied sedimentary material for a great thickness of rocks during the life of the Glenkiln fauna of Graptolites, or, in other words, during the Upper Llandeilo period, while continuous deposition proceeded at a short distance to the southwards.[3] This unconformability probably marks the southern line of the area of disturbance at the period when the Ballantrae rocks of the Highland border were involved along with the Highland schists.

The study of Palæontology has contributed greatly towards the correlation of separate areas occupied by Old Red Sandstone strata in Scotland during the period under consideration. Thus, the outlying volcanic and sedimentary rocks of Lorne have been proved to be of Lower Old Red Sandstone age by their containing a species of *Cephalaspis*, determined by Dr Traquair to be nearly allied to *C. Lyelli*, as well as other forms of life, like those found in Forfarshire, such as *Pterygotus anglicus*, *Kampecaris*, and *Parka decipiens*. The discovery of these fossils was made in 1897 by Mr Macconochie, under the superintendence of Mr Symes, while carrying on the Geological Survey of Argyleshire.[4] In the same strata,

[1] *Mem. Geol. Sur.*, "The Silurian Rocks of Britain," pp. 422, 429, 1900.

[2] *Quart. Jour. Geol. Soc.*, "The Girvan Succession," pp. 555-593, 1882; *Mem. Geol. Sur.*, "The Silurian Rocks of Britain," pp. 487, 488, 1900.

[3] *Mem. Geol. Sur.*, "The Silurian Rocks of Britain," p. 484, 1890.

[4] *Nature*, vol. lvi. pp. 157, 158, 1897; *Mem. Geol. Sur.*, "Summary of Progress for 1897," p. 82, 1898.

Mr Tait in 1898 found a species of *Mesacanthus* and some badly-preserved Ostracods, which Professor T. Rupert Jones considered to resemble Devonian forms. This is the first record of Ostracods from the Lower Old Red Sandstone of Scotland. By means of these discoveries the Lorne strata are shown to be of the same age as those of Forfarshire to the south of the Grampians, and not, as might seem more natural, to those of the Morayshire basin, a long tongue of which stretches far westwards across Inverness-shire along the line of the Great Glen.

With regard to the correlation of the Lower Old Red Sandstone strata on both sides of the Carboniferous rocks in the central valley, Dr Traquair had identified the head-shield of a *Cephalaspis* of *C. Lyelli* type from the Lower Old Red Sandstone of Lesmahagow in Lanarkshire, which was discovered by Mr William Clarkson, and presented to the late Dr Hunter-Selkirk. A similar form of *Cephalaspis* has also been found in equivalent strata near Lanfine, in Ayrshire, within the same region. These records show that the two great groups of conglomerates, sandstones and volcanic rocks, although separated by overlying newer Palæozoic rocks, are of the same age, and are probably connected beneath.

Dr Traquair has also demonstrated the close relationship of the Fish Fauna of the Lower Old Red Sandstone of Scotland, on the south side of the Grampians, with that of the west of England and the Welsh border.

In his study of the Fishes of the Old Red Sandstone, Dr Traquair shows that not a single species and only two genera are common to the Lower Old Red Sandstone beds south of the Grampians and those of the Moray Firth basin north of that range, or, in other words, in strata belonging to Lakes "Caledonia" and "Orcadie" respectively. On the hypothesis that these deposits may have taken place simultaneously in separate land-locked basins, such a divergence might be accounted for; but Mr Kidston informs me that not one species of Plant is common to the two sets of strata, so that a strong presumption is raised that they were laid down at two different geological periods. Other lines of evidence also tend towards this latter conclusion.

Dr Traquair further shows that the Old Red Sandstone of the Moray Firth basin can be separated into three life-zones, characterised by separate groups of Fishes, viz.:—

(*a*) A lower or "Achanarras" group, characterised by species of *Pterichthys*. This is the only group found on the south side of the Moray Firth.

(*b*) A middle or "Thurso" group, characterised by *Thursius pholidotus* and *Coccosteus minor*.

(*c*) An upper or "John o' Groats" group, characterised by *Tristichopterus alatus* and *Microbrachius Dicki*.

The two latter groups have, as yet, been observed only in Caithness, Sutherland, and Orkney.

From the fact that the Fishes of the "John o' Groats" group have strong affinities with fishes from the Upper Devonian rocks of Canada, Dr Traquair considered that the strata north of the Grampians, containing these three faunas, should be looked on as a middle division of the Old Red Sandstone, intermediate between the Lower Old Red Sandstone of Forfarshire and the Upper Old Red Sandstone. This view would thus revive the Middle Old Red Sandstone of Murchison.

Dr Flett, during late years, has proved the presence of these three distinct Fish Faunas in the Old Red Sandstone rocks of Orkney.[1] In 1896 he recorded the discovery of the "John o' Groats" beds with *Microbrachius* and *Tristichopterus* in Deerness, on the mainland of Orkney. In 1898 he had mapped the "John o' Groats" zone over a considerable area in Orkney, and announced the discovery of *Coccosteus minor* and *Thursius pholidotus* in rocks underlying the beds of that zone. He also recorded a new species of *Asterolepis* from these latter beds, which he believes to be the type species of a special subzone. The Stromness beds, as has been long known, hold the Fishes of the Achanarras zone of Dr Traquair. Dr Flett has therefore shown that the Orkney rocks are in complete accord with those of the mainland of Scotland.

With regard to the Upper Old Red Sandstone in Scotland, Dr Traquair has shown that it is capable of being sub-

[1] *Trans. Roy. Soc. Edin.*, vol. xxxix. p. 383, 1898.

divided by means of certain special life-zones, characterised by distinct groups of Fishes.

On the south side of the Grampians he has only definitely recognised one zone, viz., that of "Dura Den." In the Upper Old Red Sandstone, on the north side of the Grampians and a little on the south side of the Moray Firth, he shows that the Fishes contained in the Nairn Sandstones are different from those of the Elgin Sandstones, and are characterised by *Asterolepis maxima*, while *Bothriolepis major* is characteristic of the Elgin beds. Following up a suggestion of Mr Wm. Taylor of Llanbryde, that the fine-grained sandstones of Rosebrae, Elgin, belong to a yet higher horizon than the Alves beds, Dr Traquair shows that they contain fishes allying the fauna to that of Dura Den.

The exact position of the Old Red Sandstone of Shetland has hitherto been very uncertain. Dr Flett, however, has lately shown that the rocks of Bressay contain a Fish Fauna which, according to Dr Traquair's determination, indicates that, in part at least, they are of Upper Old Red Sandstone age, and that they supply a link between the John o' Groats and the Nairn beds.

Strenuous attempts are at present being made to find out whether the Carboniferous rocks of Scotland are capable of being separated into special life-zones. As regards the marine invertebrate life contained in them, this seems a difficult task; but, as might be expected, the vertebrate life lends itself more readily to that end, and Dr Traquair has clearly proved that, as far as the Fishes are concerned, the formation is sharply divided into two great life-zones, the line of separation lying at the base of the Millstone Grit.

From the study of the Plants, Mr Kidston comes practically to the same conclusion, the dividing line between the Upper and Lower Carboniferous floras being also at the base of the Millstone Grit. The Lower Carboniferous flora is characterised by *Lepidodendron veltheimianum*. In it *Sigillaria* and *Lepidophloios* are present, but are rare, while *Astrocalamites* is abundant and *Calamites* extremely rare. *Callymatotheca affinis* is a very characteristic fern of the lower rocks of the zone, and that of the Calciferous Sandstones seem to

contain certain forms in great abundance. The Upper Carboniferous flora is characterised chiefly by the abundance of Ferns, Calamites, Lepidodendra, Sigillarias, and Cordaites.[1]

Mr Kidston still further divides the Coal-Measures into three groups, each more or less characterised by the greater abundance of certain forms than in the other subdivisions. The Coal-Measures of Scotland he correlates with the lowest of these three subdivisions, and the Red, or Upper Coal-Measures of Scotland, with his middle zone.[2]

Mr Kirkby, from his study of the Ostracoda, shows that certain forms are restricted to a less thickness of strata than either the fishes or the plants.

From the evidence obtained from fossils, the late Mr Jas. Thomson, Mr Wünsch, and other members of the Glasgow Geological Society showed that strata in the island of Arran, which were considered by some as belonging to the Upper Old Red Sandstone formation, are of Lower Carboniferous age. A suite of Plants found in the Locherim Burn, near Corrie, by M. W. Ivison Macadam, was shown by Mr Kidston to be of Lower Carboniferous type. During the progress of the Geological Survey in Arran these points were corroborated, and the various subdivisions of the Carboniferous system from the Calciferous Sandstones up to the Coal-Measures were mapped in detail by Mr Wm. Gunn,[3] and large collections of fossils were made by Messrs Macconochie and Tait. From the study of these fossils it has been proved that strata of Coal-Measure age occur in five or six separate localities, thus affording a new point in the geology of the island.[4]

During the progress of the Geological Survey in Argyleshire, Mr H. Kynaston mapped a small area of red-stained sandstones in the valley of the Awe, near Taynuilt,[5] which was first noticed by Macculloch. From this a small suite of fossils was obtained by Mr Tait. The Plants were pronounced by Mr Kidston to be of Lower Carboniferous type,

[1] R. Kidston, *Proc. Roy. Phys. Soc.*, vol. xii. pp. 183-257, 1884.

[2] R. Kidston, *Proc. Roy. Phys. Soc.*, vol. xii. pp. 183-257, 1884.

[3] *Mem. Geol. Sur.*, "Summary of Progress for 1897," p. 112, 1898.

[4] *Mem. Geol. Sur.*, "Summary of Progress for 1897," pp. 113-123, 1898.

[5] *Mem. Geol. Sur.*, "Summary of Progress for 1898," p. 129, 1899.

while a modioliform shell, like *Modiola Macadami*, one of the commonest fossils of the Calciferous Sandstones of Fife and Liddesdale, was also found to occur. This outlier may now be looked upon with confidence as belonging to the Carboniferous formation, and is thus the second patch noted north of the Grampians, the other being that discovered by Professor Judd on the shores of the Sound of Mull in 1877.[1]

Before the time under consideration, the controversy regarding the horizon of the Reptiliferous Sandstones of Elgin had already been practically ended in favour of their Triassic age through the researches of Huxley and others. The discovery in them of the Dicynodont remains and those of the other Anomodontia described by E. T. Newton, in his Memoir published by the Royal Society, strongly confirms this view.[2]

Prior to the time that the Geological Survey commenced its operations in Arran, the red sandstones near the Cock of Arran had been conclusively proved, by the late James Thomson, to be newer than the Carboniferous Limestone. He showed that fossils of that age were contained in the derivative limestone boulders which make up their basement conglomerates, but this evidence only led him to the conclusion that the newer rocks probably belonged to the Millstone Grit. The work of the Geological Survey carried on by Mr Gunn proved that the Red Sandstones and conglomerates south of the Cock of Arran rest unconformably on the Coal-Measures, proved by their plant remains as above stated, affording a strong presumption that they are either of Permian or Triassic age. Similar evidence of the unconformability of the Red Sandstones to the Coal-Measures was found to exist near Corrie and Brodick, and also near the head of the Benlister Burn and Sliddery Water in the south of the island. Although no direct fossil evidence was obtained from the red sandstones beyond some indeterminable Plant remains, Mr Gunn inferred that the rocks are of Triassic age; the red sandstones and conglomerates at the base representing the Bunter, and the overlying red marls and yellowish

[1] *Quart. Jour. Geol. Soc.*, vol. xxxiv. p. 685.

[2] *Phil. Trans.*, vol. clxxxiv. p. 431, 1893; *Ibid.*, vol. clxxxv. p. 573, 1894.

sandy beds, the Keuper subdivision. This surmise has received unexpected corroboration through evidence afforded by fossils. A large volcanic neck or vent was found about the centre of the island, between Brodick and Blackwaterfoot, which pierces the surrounding formations from the Lower Old Red Sandstone up to the red Triassic marls. A large detached mass of strata, acres in extent, composed of red and whitish marls and black shales and limestone bands, occurs embedded in the agglomerate and intrusive igneous rocks that fill the vent. From the dark shales of this mass Mr Macconochie obtained a suite of characteristic fossils of the *Avicula contorta* zone, showing that the black shales are of Rhætic age.[1] The underlying red marls are identical with those which form the highest beds of the supposed Trias in the immediate vicinity. But this does not exhaust all the evidence obtained from fossils afforded by this vent, for other masses of sedimentary strata were found embedded among the volcanic materials. One of these masses afforded a large suite of fossils, determined by Mr E. T. Newton to be of Lower Lias Age, and some limestone blocks have been proved by him to contain characteristic Upper Cretaceous forms.[2] Thus the vent is shown to be of later date than the Upper Cretaceous, and is doubtless coeval with the great volcanic period of Antrim, Mull, and Skye. Further, as most of the types of the plutonic and intrusive igneous rocks of the island are found to have welled up this vent, a strong presumption is raised that the great plutonic masses and intrusive sheets found outside the neck are also of Tertiary age; but what appeals most to the imagination is the impressive evidence thus obtained, that Secondary Strata must have overlain this part of the south of Scotland which have been entirely removed by denudation since Tertiary time.

The work done in Scotland during the period under review has thoroughly established the paramount value of Palæontology in the interpretation of the geological structure of the country.

[1] *Mem. Geol. Sur.*, "Summary of Progress for 1899," pp. 132-134, 1900.

[2] *Mem. Geol. Sur.*, "Summary of Progress for 1899," pp. 132-134, 1900.

XXVI. *Results of Meteorological Observations taken in Edinburgh during* 1900. By R. C. MOSSMAN, F.R.S.E., F.R.Met.Soc.

(Read 20th March 1901.)

The observations discussed in this paper have been made twice daily, at the hours of 9 A.M. and 9 P.M., the instruments employed being those described in former reports. In the author's absence from home during the greater part of the last quarter of the year, it was not always possible to obtain the services of a first-class observer. The observations taken during this period were accordingly carefully compared with those made at the Blackford Hill Observatory, situated about a mile and a half to the south-west. A few interpolations had to be made in the sunshine record owing to the instrument getting out of adjustment, but the general results are not appreciably affected, as the results obtained from the record utilised, viz., that kept at the Royal Botanic Garden, closely approximate to those obtained at my station during the last ten years.

The kite-flying experiments referred to in previous reports have been successfully prosecuted during the past year at Leadburn, under the direction of Mr Anderson, and several noteworthy results have been obtained bearing on the meteorology of the upper air.

REMARKS ON THE METEOROLOGY OF 1900.

In *January* mean pressure and bright sunshine were in close accordance with the normal, but the rainfall, 3·4 inches, was in excess of the average, falling on the large number of 29 days, the only month with so many wet days during the last 45 years being July 1882. Mean tempera-

ture exceeded the normal by 2°·3, there being an almost complete absence of frost or snow. The unusual phenomenon of a winter thunderstorm was observed on the 19th at 5.45 P.M., and a bright aurora was seen the same evening.

February was characterised by a low mean pressure, very low temperature, a precipitation nearly double the average, and a slight deficiency of sunshine. During the first half of the month very cold weather prevailed, with frequent gales and heavy snow. The minimum temperature for the year, 17°, was recorded on the 8th, and the lowest barometric pressure, 28·391 inches, on the 19th, on which day the rainfall amounted to the large quantity of 1·28 inches.

In *March* the mean barometric pressure was over two-tenths of an inch above the normal, the anti-cyclonic conditions being accompanied by a low temperature, small rainfall, and much cloud. Winds were light, and almost wholly from the north and east.

In *April* and *May* the mean pressure was in close accordance with the average, temperature was above the normal, and only two-thirds of the average precipitation was registered. There was an excess of bright sunshine in April, but in May, usually the sunniest month of the year, there was a rather marked defect.

The weather of *June* was characterised by a slight excess of temperature and rainfall, but pressure and sunshine were both less than the normal. A thunderstorm, accompanied with great darkness and blinding flashes of lightning, occurred on the evening of the 12th, being the severest experienced in Edinburgh since the memorable visitation of the 12th of August 1884.

In *July* the mean temperature of the air was 61°, being the highest July temperature in the Edinburgh district since 1887. The most striking feature of the meteorology of the month was the unusual nocturnal warmth, the mean minimum temperature being 54°·2. The only months since 1840 in which the average night temperature was higher were the Julys of 1852 and 1855, with means of 56°·4 and 54°·9 respectively. As regards the other elements of climate,

pressure was above the normal, but sunshine and rainfall both slightly under the average.

The characteristic features of the weather of *August* were a very high mean barometric pressure, a low temperature, very heavy rainfall, and an unusual deficiency of bright sunshine. The mean temperature was 56°·6, being the lowest since 1888, when it was a degree lower; the total rainfall registered was 5·68 inches, the greatest since 1881, with 6·07 inches. During the first half of the month, the bright sunshine amounted to 66 hours, but the last fortnight was exceptionally dull, only 13 hours being recorded, the total of 79 hours being the least registered in August since 1866, which had 73 hours. Owing to barometric pressure being much higher in the north than in the south, the prevailing winds were from the east, which explains the low temperature, heavy rainfall, and general cloudiness of the month. Some notable meteorological phenomena were observed, notably the rainstorm of the 6th, when 2 inches of rain fell, and the waterspout of the 23rd, when in 18 minutes the Richard pluviograph recorded 0·62 inch of rain and hail, or at the rate of 2·07 inches per hour. As regards the rainfall on the 6th, it was the heaviest daily fall in Edinburgh for 21 years, while the waterspout of the 23rd was the third well-authenticated appearance of this phenomenon in the last 200 years, the only previous cases occurring on 13th August 1744, when a waterspout burst on the west side of Arthur's Seat, dividing into two portions, one of which tore up the channel under the Lion's Head known as the Gutted Haddie, while the other flowed down the west side and inundated the village of Duddingston, carrying away the gable of the most westerly cottage, and flooding the loch over the adjacent meadows.

Another waterspout was seen on 14th May 1826, a description of which appeared in volume ix. of the *Edinburgh Journal of Science.*

In *September* mean pressure was just the average, there being an excess of temperature amounting to a degree and a half. Rainfall was considerably below the normal; while sunshine was slightly above the average. Taken as a whole, the month was comparatively featureless.

In *October* mean pressure was again in close accordance with the normal, temperature being a little below the average. During the month 4·9 inches of rain fell, being double the average, and the greatest in October since 1864. Sunshine was rather deficient.

November was characterised by an excess of pressure, a high mean temperature, barely half the average amount of sunshine, accompanied by an enormous rainfall, more than double the average quantity being precipitated. The total downfall for the month was 5·42 inches, being the greatest in November since 1772, when 5·66 inches fell.

In *December* mean pressure and sunshine were in close accordance with the normal, but the extreme mildness of the air and large rainfall were again noticeable features. The mean temperature was 44°·3, or 5°·9 in excess of the average, the only warmer Decembers since the register commenced in 1764 being those of 1842, 1843, and 1857. The rainfall amounted to the large quantity of 4·43 inches, or 79 per cent. above the average.

During the last quarter of the year, 14·72 inches of rain fell, against an average of 7·52 inches, an excess of 96 per cent. Reference to the monthly rainfall tables taken in Edinburgh since the year 1785 shows that the greatest downfall previously recorded for the last quarter of the year was 13·38 inches, in 1860, or an inch and a half less than in 1900.

The values for the *year* as a whole show a defect of pressure of ·014 inch; a mean temperature exceeding the average by close on a degree; a total rainfall of 38·72 inches, being 8·80 inches above the average, and the greatest since 1877, when over 42½ inches fell. During the year, only 1013 hours of bright sunshine left their impress on the recorder, out of a total possible of 4478, this being the smallest amount of sunshine since 1867, when the non-instrumental record showed a total of only 980 hours. In both these years the deficiency of sunshine was most marked in the three summer months of June, July, and August, the total for the period under review being 283 hours in 1867, and 332 hours in 1900.

NOTEWORTHY PHENOMENA IN THE METEOROLOGY OF 1900.

Highest barometric reading 30·643 inches, on March 13th.
Lowest barometric reading 28·391 inches, on February 19th.
Highest temperature in shade 77°·4, on July 10th.
Lowest temperature in shade 17°·0, on February 8th.
Highest temperature in sun's rays (black bulb thermometer in *vacuo*) 133°·5, on July 18th.
Lowest temperature on grass 10°·9, on February 12th.
Sunniest day June 3rd, with 13·1 hours bright sunshine.
Greatest daily rainfall 2·00 inches, on August 6th.

	Barometer at 32° and Mean Sea-Level.						Temperature in Shade 4 Feet above Grass.													
															Departure from Average 1851-1900.					
	Highest in Month.	Lowest in Month.	Monthly Range.	Difference from Average 1840–1900.	Mean Pressure.	Difference from Average 1770–1900.	Highest in Month.	Lowest in Month.	Monthly Range.	Mean Temperature.	Mean of all the Highest.	Mean of all the Lowest.	Mean Daily Range.	Mean Variability of Temperature.	Mean Max.	Mean Min.	Mean Daily Range.	Mean Temp.	Mean Variability of Temp	Diff. from Aver. 1764-1900, Mean Temp.
	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	°	°	°	°	°	°	°	°	°	°	°	°	°	°
January, ...	30·409	29·177	1·232	– ·357	29·801	– ·019	51·9	29·8	22·1	39·2	43·0	35·5	7·5	2·4	+0·7	+1·9	–1·2	+1·3	–0·7	+2·3
February, ...	30·294	28·391	1·903	+ ·461	29·546	– ·265	52·7	17·0	35·7	34·1	38·8	29·4	9·4	2·7	–4·8	–4·4	–0·4	–4·6	–0·1	–4·2
March, ...	30·643	29·330	1·313	– ·120	30·078	+ ·214	54·8	21·1	33·7	38·5	44·0	33·0	11·0	2·0	–1·9	–1·6	–0·3	–1·8	–0·7	–1·8
April, ...	30·483	29·142	1·341	+ ·156	29·860	– ·032	71·9	30·2	41·7	46·3	54·2	38·4	15·8	3·2	+2·6	+0·2	+2·4	+1·4	+0·5	+1·5
May, ...	30·465	29·158	1·307	+ ·202	29·936	– ·004	68·7	37·2	31·5	50·6	57·7	43·4	14·3	3·0	+0·7	+1·1	–0·4	+0·9	+0·2	+0·7
June, ...	30·477	29·457	1·020	+ ·068	29·888	– ·045	75·6	41·4	34·2	56·4	63·4	49·4	14·0	2·9	+0·3	+1·2	–0·9	+0·8	–0·1	+0·7
July, ...	30·274	29·448	0·826	– ·118	29·930	+ ·050	77·4	46·1	31·3	61·0	67·8	54·2	13·6	2·5	+2·2	+2·9	–0·7	+2·6	0·0	+2·4
August, ...	30·440	29·273	1·167	+ ·162	29·952	+ ·076	76·3	43·0	33·3	56·6	62·5	50·8	11·7	2·4	–2·1	–0·1	–2·0	–1·1	0·0	–1·2
September, . . .	30·496	29·208	1·288	+ ·096	30·008	+ ·133	70·2	38·0	32·2	55·1	62·3	47·9	14·4	3·0	+1·9	+0·6	+1·3	+1·2	+0·5	+1·5
October, ...	30·565	29·187	1·378	– ·090	29·811	– ·002	65·3	31·4	33·9	46·7	52·0	41·3	10·7	3·4	–0·8	–0·4	–0·4	–0·6	+0·6	–0·6
November, . . .	30·540	29·058	1·482	– ·089	29·697	– ·106	58·4	29·0	29·4	43·0	47·0	39·1	7·9	3·0	+0·6	+2·1	–1·5	+1·3	–0·1	+2·0
December, . . .	30·227	28·448	1·779	+ ·181	29·639	– ·159	57·1	32·4	24·7	44·3	47·8	40·8	7·0	2·7	+4·6	+6·4	–1·8	+5·5	–0·6	+5·9
Year, ...	30·643	28·391	2·252	+ ·062	29·845	– ·014	77·4	17·0	60·4	47·6	53·3	41·9	11·4	2·8	+0·3	+0·8	–0·5	+0·6	0·0	+0·7

	Rainfall.					Relative Humidity.		Solar and Terrestrial Radiation.			
	Total Fall.	Diff. from Average 122 years.	Max. in 24 hours.	No. of days on which ·01 in. or more fell.	Diff. from Average 1877–1896.	Relative Humidity, Saturation=100.	Diff. from Average 1862-1900.	Mean Black Bulb in Sun.	Average Excess over Shade Maximum.	Mean Bright Bulb on Grass.	Mean Difference from Shade Min.
	Ins.	Ins.	Ins.	Days.	Days.	%	%	°	°	°	°
January, .	3·38	+0·95	0·91	29	+13	86	0	57·8	14·8	32·8	2·7
February. .	3·57	+1·61	1·28	12	− 2	84	−2	68·7	29·9	24·8	4·6
March, . .	1·06	−0·91	0·26	10	− 5	81	−3	78·1	34·1	29·3	3·7
April, . .	1·35	−0·71	0·46	13	− 1	81	+1	98·2	44·0	34·4	4·0
May, . .	1·35	−0·74	0·42	13	− 1	75	−3	107·5	49·8	40·3	3·1
June, .	2·83	+0·73	1·18	18	+ 4	82	+4	109·5	46·1	47·9	1·5
July, . .	2·92	−0·44	0·53	17	− 1	80	+1	114·3	46·5	52·5	1·7
August, .	5·68	+2·20	2·00	19	0	83	+1	98·4	35·9	49·6	1·2
September,	1·86	−1·06	0·58	17	+ 1	82	−1	102·0	39·7	45·5	2·4
October, .	4·87	+2·47	0·97	21	+ 4	84	−2	90·0	38·0	40·0	1·3
November,	5·42	+3·78	0·81	22	+ 5	89	+2	67·5	20·5	36·3	2·8
December,	4·43	+1·95	0·76	27	+11	82	−4	64·4	16·6	37·9	2·9
Year, . .	38·72	+8·83	2·00	218	+28	82	−1	88·0	34·7	39·3	2·6

Bright Sunshine and Cloud.

	Total Recorded.	Percentage of possible Duration.	Difference from Average 30 years.	Greatest in 1 Day	No. of Sunless Days.	Difference from Average 30 years.	Mean Amount of Cloud, Overcast Sky or Fog=100.	Difference from Average 1891-1900.
	Hrs.	%	%	Hrs.	Days.			
January, ...	35	15	− 6	3·7	15	+ 4	70	+ 5
February, . . .	59	22	− 4	7·1	10	+ 5	54	− 5
March, ...	75	21	− 9	7·0	9	+ 1	62	+ 3
April, ...	143	34	+ 4	11·2	3	− 2	64	− 3
May, ...	144	29	− 3	12·4	4	0	88	+18
June, ...	115	22	− 6	13·1	5	+ 2	84	+11
July, ...	138	26	− 3	12·3	5	+ 1	84	+ 8
August, ...	79	17	−13	10·1	8	+ 3	80	+ 7
September, . . .	117	31	0	9·6	5	+ 1	54	− 7
October, ...	65	20	− 9	8·2	8	+ 1	56	− 4
November, . . .	22	9	−15	5·0	19	+10	64	− 3
December, . . .	21	10	− 9	3·8	14	0	65	0
Year, ...	1013	23	− 4	13·1	105	+26	69	+ 3

Wind from Observations made at 9 A.M. *and* 9 P.M. *Number of Days it blew from certain directions.*

	N.	N.E.	E.	S.E.	S.	S.W.	W.	N.W.	Calm or Variable.	Mean Wind Velocity. Miles per hour.
January,	2	1	4	1	0	3	14	3	3	9·1
February,	1	2	6	3	0	2	9	3	2	6·4
March,	2	4	12	0	0	1	8	2	2	5·6
April,	1	1	5	2	1	2	13	4	1	8·0
May,	1	1	10	1	2	3	7	2	4	7·3
June,	1	2	9	5	1	1	7	3	1	5·6
July,	0	0	6	0	2	2	13	4	4	6·7
August,	2	1	13	1	0	2	5	2	5	5·8
September,	1	1	1	1	0	1	18	2	5	7·1
October,	2	0	3	0	1	3	17	2	3	8·6
November,	0	2	8	2	2	2	10	1	3	10·4
December,	1	2	2	2	3	6	13	2	0	11·8
Year,	14	17	79	18	12	28	134	30	33	7·7

Number of Times the following Phenomena were observed.

	Thunderstorms.	Lightning without Thunder.	Gales.	Snow.	Hail.	Fog.	Auroras.	Halos.	Rainbows.	Hoar Frost.	Frost in Shade.	Frost on Grass.
January,	1	0	0	6	2	1	1	0	2	0	6	16
February,	0	0	1	11	0	1	0	1	0	3	18	23
March,	0	0	1	7	1	1	0	4	0	4	14	18
April,	0	0	0	0	0	0	0	1	0	1	3	3
May,	0	0	0	0	1	0	0	0	0	0	0	0
June,	5	1	1	0	2	3	0	0	0	0	0	0
July,	1	0	0	0	0	1	0	0	0	0	0	0
August,	2	0	0	0	1	2	0	2	0	0	0	0
September,	0	0	1	0	0	2	0	0	1	0	0	0
October,	1	0	1	0	1	0	0	4	1	1	1	6
November,	0	0	1	0	2	4	0	0	0	2	3	9
December,	0	0	6	0	0	0	0	6	0	0	0	4
Year,	10	1	12	24	10	15	1	18	4	11	45	79

XXVII. *Simpler Methods in Crystallography.* Part. II. (1) Maps of Anorthic Crystals; (2) The Determination of Crystalline Forms; (3) Methods of Drawing Crystals. By J. G. GOODCHILD, H.M. Geol. Survey, F.G.S., F.Z.S. (Continued from p. 359 of the present volume.)

(Read 17th April 1901.)

The projection of stereograms of crystals belonging to the Anorthic System involves much more complicated methods of work than do any of those described in the former paper. But though the principle of construction by proportional parts, as applied to the other systems, is equally applicable to this if these principles are rightly understood, it may be as well to describe my own methods of work in making maps relating to this system of crystals.

In the other systems the poles projected to the surface of the sphere as normals to each of the faces group themselves about certain planes with the particular grade of symmetry proper to each system. In the Anorthic System, on the other hand, no such symmetry is traceable, and much of the trouble involved in making these maps arises from this cause, or, from what amounts to the same thing, to the fact that the crystallographic axes and the axes of reference are in no case the same.

In drawing these stereograms, it has, of course, to be borne in mind that the poles and their zones, supposed to be drawn on to the sphere of projection, may be viewed in any direction. We may suppose, for instance, that we look at the inner surface of the sphere from the opposite outer surface at *c*, or at *b*, or at *a*, just as occasion requires, and in like manner we are at liberty to project on to the plane of projection from any one point on the primitive to any other, as may be needed in each case.

I have made a large number of projections of anorthic crystals, chiefly with the object of interpreting the morphology of actual crystals, but partly also with the object of selecting one species which may serve as a typical example of this system. Perhaps, all things considered, the best for the purpose is Rhodonite (Dana's number 335), a manganese

metasilicate. The elements of the crystal as accepted by Dana (Sixth edition, "Syst. Min.," p. 378) are as follows:— $a : b : c = 1{\cdot}07285 : 1 : {\cdot}62127$; $\alpha = 103^\circ\ 18'\ 7''$; $\beta = 108^\circ\ 44'\ 8''$; $\gamma = 81^\circ\ 39'\ 16''$.

The Construction of Solid Projections of Anorthic Crystals.— In commencing this work, which is fraught with far greater difficulties than the descriptions hitherto published would lead one to suppose, it is as well first to attack the problems by concrete methods. For this purpose, therefore, take a ball of soft wood: a convenient size is 5 inches in diameter, which is the size I have used for the purpose in the Edinburgh Museum. A good pair of spring dividers is likely to be of much use, and one of the points of this instrument should be bent inwards about 25 degrees, and both of them kept as fine as possible. The other requisites are a table of chords, and a good diagonal scale to 2½ inches as a unit. The preliminary step consists in marking three great circles on the ball exactly at right angles to each other. For this purpose select any point on the ball, and from this as a centre, with the radius 1·414 taken from the diagonal scale, describe on the ball a diametral line. From any four points in this, about at right angles to each other, describe arcs at the opposite pole, so as to mark the centre of the sphere opposite the one first selected. Then, from this, check the first diametral line, so as to eliminate any possible errors. Next, with the same radius, draw another great circle passing through the poles already determined, and from the points where this circle intersects the first draw the third great circle, afterwards finding its second pole and checking again, as before. Mark one pole C, and the one opposite it C^1. Also mark the other poles in like manner A, A^1, and B, B^1 respectively. The circle ABA^1B^1 is to be the primitive, and CC^1 are the poles of the AXES OF REFERENCE. We may conveniently refer to all three circles as the GREAT CIRCLES OF REFERENCE, to distinguish them from the crystallographic zones.

These poles of reference need not all, necessarily, coincide with the poles of any crystallographic faces in the Anorthic System, though they may do so in a few cases.

We now take the elements of Rhodonite and set to work to plot them on the ball. We have, first, to lay down the angle β, which the books informs us is the angle between c and a. *It is not so.* It is the angle between the vertical angle of reference CC^1 and an axis parallel to the inclined face c, as measured in the direction CA. This is quite another thing. In Rhodonite the angle β is 108° 44′, which is measured from above on the face chosen as the front, from C towards C^1. As the circle of reference AC is conventionally regarded as coinciding with ac in position, we may measure upon AC^1 from A and from A^1C from A^1 the excess of β over a right angle, *i.e.*, 18° 44′, the chord of which is ·325. While the spring dividers are set to this chord, describe small circles with this radius around C, C^1, which will be needed for the determination of the pole of the crystallographic axis c, presently to be defined more exactly.

We have next to set out the angle α, which is usually given as the angle between c and b. *It is not so.* What it is really is the angle between the vertical axis of reference C, and a radius from O parallel to the inclination of the face c as measured in the direction of CB. Had these misleading statements not been made and copied into one book after another, more of those people who have tried to learn a little about crystallography might have gone farther than the threshold.

To set off α, which is 103° 18′ in Rhodonite, take the chord of that angle, which may be taken at 1·568, and describe arcs of circles around B, B^1 from C, C^1 as centres. Then, also from C, C^1 as centres, take the chord of 13° 18′, which is ·2316, and describe small circles cutting those previously drawn and their poles of reference. The points of intersection so obtained mark the poles of the crystallographic axis c, which is that of the basal pinacoid (001).

The step to be taken next is to lay down the angle γ, which, we are told, is the angle between a and b. To set this out upon the ball, take the chord of 81° 39′ (the angle in question in the species chosen), which is 1·307, and from

A^1 towards B, and from the corresponding points opposite, describe arcs intersecting those already drawn to represent the angle α. The points so determined are the poles of the crystallographic axis *b* (010).

We have, finally, to project the crystallographic axes *a* and *b* on to the primitive. To do so draw lines from these poles to C (not to *c*), and the points where these lines intersect the primitive are the positions, respectively, of the *a* and *b* from which the measurements given in all the text-books are taken. *a*, *b*, *c* being thus determined, the positions of the remainder of the leading forms may be laid down, if desired, by means of the spring dividers, from any table of angles, and the various zones connecting these points may be drawn upon the ball in the manner previously described.

With the poles and zones in a concrete form before one, the projection of a stereogram, or of a gnomonogram, may be rendered much simpler than could be at all possible without this aid.

Construction of Maps of Anorthic Crystals.—In proceeding to draw the maps, it is a good plan to lay down the working lines for the projection upon two or more separate sheets of paper, and afterwards to transfer the points and lines so determined to another sheet, which is to be the fair copy of the complete map. It is well to have plenty of margin around each of the working maps, and to choose as large a radius as convenient. Any dimensions between 2½ inches and 5 inches radius may be selected. The primitives must, of course, be all of exactly the same size.

1. *The projection of c* (001).—Draw two diameters at right angles to each other, to serve as axes of reference, mark the extremities of the front-and-back one XX^1, those of the right-and-left one YY^1, and mark the centre Z: the sphere in this case is supposed to be viewed from above, or in the direction of OZ, the axis of the prism zone, or vertical axis of reference. It is customary to draw the *a* axis in Anorthic crystal maps parallel with the right and left sides of the paper. Therefore the points where XX^1, regarded as of indefinite length, cut the primitive, will serve for the projection of the poles aa^1.

The angle between a and b, *as measured along the primitive*, is given by Dana as 94° ·26′, which is to be set off towards the right from Xa, and towards the right from a^1 at the back. Sign the points so determined b, b^1. This is a simpler procedure than that of computing the angle by graphic or other methods from the spherical triangle formed by the angles $\alpha\beta\gamma$ from C; and with the solid sphere of projection represented by the ball kept constantly in view, there is no risk of any confusion arising by adopting this method.

Next deal with the angle β, which is that between the vertical axis of reference C (in the present case coincident with Z) and a plane passing through the origin O, and inclined so as to be parallel to the face c, the basal pinacoid (001). As we have assumed that a is already laid down upon the primitive, we need not at present consider β in relation to that; but as the inclination of the face c (001) is parallel to a radius on a plane passing through O inclined towards a from C at the angle in question, it follows that the position of c (001) in relation to C may be in part determined accordingly; one mode would be that of setting off the projection of an arc of a small circle from C as a centre, and with a radius equal to the excess of β over a right angle, *i.e.*, 18° 44′, and then finding the intersection of this by another arc of a small circle bearing the same relation to a. The other and simpler plan for laying down the position of c (001) upon the stereogram is as follows:—Conceive, first, that the sphere of projection is viewed from b, which in this case takes the place of Z or O. Y^1 then stands for the upper half of the vertical axis of reference, XX^1 remaining as before. From Y^1 set off the chord of the angle β past X towards Y. This angle is 108° 44′, of which the chord is ·3255 in excess of that of a right angle. For the present purpose it will suffice to measure off this latter on the primitive from Y^1 toward X. The angle from Y^1, so determined, is the inclination of a plane parallel to the cystallographic face c (001) measured from O towards a (100). Project this point upon the axis of reference XX^1 from Y, and transfer it to the final copy. Next, in this latter, draw an arc of a great circle passing through this point and b, b^1. The zone so

projected is the projection of bcb^1, the zone of the brachy-domes.

Now conceive that the sphere of projection is viewed from X in the direction of X^1. YY^1 remain as the right-and-left axes of reference, as before; but the vertical axis of reference stands for ZZ^1, Z being uppermost. We have now to project the inclination of the trace of a plane passing through the origin O (or Z), and inclined parallel to the crystallographic face *c* (001), as measured in the direction of XY. The angle in question is measured from the vertical axis of reference, and is denoted by α. In Rhodonite α is 103° 18′ 7″, or 13° 18′ more than a right angle. As we are not here concerned with α in relation to *b* (010), but only to *c* (001), we simply measure off the chord of 13° 18′, which is ·2316 from Z^1, the primitive towards Y, project this angle from Z on to YY^1. Transfer the point so determined to the final copy, and draw an arc of a great circle through this and aa^1. This arc gives the projection of the zones of the macro-domes, or aca^1, and therefore the projection of *c*.

2. *Projection of the Prisms.*—The same working map will serve for both the projections already worked out and these. We have first to conceive that we are viewing the sphere of projection from the side, in the direction from *b* to b^1, and that this latter, in the present case, stands for the upper half of the vertical axis. The ratio of the vertical axis to unity (*ob*) in Rhodonite is ·62127, and that of the front-and-back crystallographic axis in the same species is 1·07285 (*i.e.*, greater than unity in this case). It is well to draw a short arc of a circle to this radius near both *a* and a^1. Then as β, the inclination of the crystallographic axis *a* in Rhodonite, is 108° 44′ 8″, measured from the vertical axis of reference C, which angle is 18° 44′ 8″ more than a right angle, set off on the primitive from *a* towards *b*, the equivalent chord ·325, and draw a line from the centre of the primitive through this point to the outer segment just mentioned. The point so determined is *a*.

Now, as the projection which is under construction is supposed to be viewed from above, in the directions parallel ZOZ^1, this length of *a* will have to be fore-shortened. Accord-

ingly, a right angle to OX is drawn from the point marking the full length of a, and the length 1·017 on OX, so determined, is the fore-shortened representative of a required.

In like manner, as b is inclined 13° 18′ 7″ below, and b^1 as much above the plane of the primitive, these are also fore-shortened by the same method of construction, so that their length on each side of the centre is less than unity by ·03 of the radius.

Connect these points representing respectively the fore-shortened a with b and b^1, and prolong the lines to the primitive. Raise perpendiculars to these lines, passing through the centre to fully the length of the radius outside the primitive in each direction. The points where these lines cut the primitive are the true projections of (110), ($1\bar{1}0$), and the lines joining these with c are the zones containing the unit hemipyramids. Draw lines outside of the primitive respectively parallel to aa^1, bb^1 to meet the prolongation of the lines through (110), (110). Proportional lengths measured upon these give the macroprisms (between a and mM) and the brachyprisms (between mM and bb^1) whose positions are required, as in the case of the other projection described in the former paper above referred to. In Rhodonite these are f (130), g (150), t (310), d (210), e ($1\bar{3}0$).

3. *Projection of the Poles of the Macrodomes.*—To draw the Macrodomes and Brachydomes, it is well to use a separate working map, as already mentioned, and to transfer the positions, when found on these, to the final copy. Firstly, we have to suppose that the sphere of projection is viewed from the side looking from b to b^1. Measure off ·62127 of the unit length on what here serves as the vertical axis of reference OY, OY^1, and draw an inclined β (the angle with the vertical axis of reference 108° 44′ 8″ already mentioned). This, of course, can be simply transferred to the present map from the one lately used. Draw lines connecting these points, and prolong them to cut the primitive. Erect perpendiculars upon them, passing through the centre, and prolonging them to a distance equal to the radius beyond the primitive. The projections of the points where these cut the primitive upon the front-and-back axis of reference OX, OX^1, give the posi-

tions through which arcs of circles are drawn from bb^1 to determine the position of the unit macrodomes (101), ($\bar{1}$01). To lay down the other macrodomes, a similar plan is adopted to that already described. Lines outside the primitive are drawn respectively parallel to aa^1 and the inclined crystallographic axis c (001), and proportional parts are measured off as already described and illustrated. Lines are drawn thence radially to the primitive, are projected to the front-and-back axis of reference OX, OX^1 from Y, and arcs of circles through bb^1, and these points define the position of the required positive and negative macrodomes on ac. These in Rhodonite are μ (401), and ρ ($\bar{2}$01), ϕ ($\bar{4}$01).

4. *Projection of the Poles of the Brachydomes.*—It happens that in Rhodonite only one brachydome has been recorded, γ (041); but as this species is in many other respects a representative one for the purpose, the mode of construction may as well be fully described. Much of the foregoing description will apply equally to this. The inclination α of b to the vertical axis of reference is 103° 18′ 7″, or 13° 18′ 7″ more than a right angle. To draw the first steps in the projection, we have to assume that we are viewing the sphere of projection from the front in the direction of aa^1. The crystallographic (or inclined) axes c and b are laid down at right angles to each other as before, and inclined to the axes of reference as if rotated through 13° 18′ 7″ (·231 of the unit measured as a chord of the primitive). Then, on the vertical axis of reference OZ, ·62127 is measured off on either side from O for cc^1, and lines are drawn from these points to the inclined crystallographic axis bb^1 at its full length, and these are prolonged to cut the primitive. Perpendiculars through these intersections are drawn through the origin O, and prolonged to the length of the radius beyond the primitive. The points so determined are projected on to the rectangular axes of reference OY, OY^1, and arcs of great circles through these from aa^1 give the position of the poles of the unit brachydomes by their intersections with bcb^1. For the other brachydomes, lines are drawn outside the primitive, parallel respectively to lines joining bb^1 and the inclination of the Oc crystallographic axis as determined by the angle α.

Proportional parts measured along these lines enable one to determine the positions of the poles required.

5. *The Projection of other Forms.*—No real difficulty need be experienced in projecting the poles of any brachypyramids or macropyramids if these instructions are carefully followed with reference to the figures already given in the former paper, and with the solid construction before one. Arcs of circles are drawn from the primitive to pass through *c*, and are intersected by other arcs passing through *bb*. Taking *z* (16.2.3) in Rhodonite for an additional example to those already given, an arc from (810) on the primitive is drawn through *c* and is intersected by another arc passing through the pole of the macrodome (16.0.3). *a* (4.1.12) again is got by the intersection of an arc from (410) through *c* with another arc through the macrodome (103).

These details may seem very complicated, and not at all in accordance with the instructions given in the text-books; but they are, in practice, much more simple than they appear in description. One is occasionally inclined to suspect that some of the writers of these text-books have never attempted the construction of these maps themselves; otherwise, if they really wished students to know how to go to work, they would have given clearer instructions for the purpose than they have done.

Anorthic Gnomonograms.—Gnomonograms as applied to the illustration of crystals belonging to other systems have been referred to in the First Part of this paper. It only remains to add now that the same system of projection is equally applicable to Anorthic Crystals. The best pole for the tangent plane to touch the sphere of projection is usually that of *c* (001). As an expeditious and simple method of determining the zonal relationships of the various poles this method has no equal, and I now invariably make use of it for that purpose as an invaluable adjunct to the stereograms. Where the poles are situated in positions too widely separated to be shown on a map of any convenient dimensions, two (or even more) maps may be advantageously used, each projected on a tangent plane suitable for the purpose in view. The

method of construction is soon mastered; and, as all the zones are shown by straight lines, many of the difficulties attendant upon the construction of stereograms are entirely avoided. It seems to me so much more convenient and practically useful to have as many zones as possible delineated so as to be easily read by inspection than it is to have to calculate them out—simple though the method of calculation referred to undoubtedly is. It may not be out of place here to remark that the methods in question are mostly, with great precision, set forth in the introductory chapter by Miller in Brooke and Miller's "Mineralogy"—one of the most valuable works on the subject in the English language, even yet.

As an example of a gnomonogram of an Anorthic crystal, the best that can be selected is either CHALCANTHITE (755), the hydrous cupric sulphate, or else AXINITE (410), the aluminium and calcium boro-silicate. Each of these represents a type of anorthism widely different from the other.

Chalcanthite is best projected on a tangent plane touching the sphere of projection at the pole of (101). For a gnomonogram to a sphere of 2½ inches' radius a sheet of paper about 3 feet wide by 18 inches across is required. The exact details of the earlier steps in the projection can easily be learned from a study of the description already given in the former Part in connection with this method of projection as applied to other systems. The circle representing the sphere in the first projection, and the various construction lines required in connection with it, may be drawn in the top left-hand corner of the paper. When this has been done, mark the position of (101) by a cross about two-thirds towards the front of the middle of the paper. Rule a line through this to the opposite edges of the paper for the zone of the macrodomes, *a-c*; and another at right angles to it extending to either side. Then take off the distances of *a* and *c* from (101) from the first projection, and sign them in the usual way. Draw a line through *a* at right angles to *ac*, and upon this mark off the positions of $(1\bar{1}0)$ and (110) taken from the first projection, and sign these respectively $M^{\prime}$, m^{1}. Then at *c* set off a line towards the left, forming the

angle γ (77°·37) with *ca* for the zone of the brachydomes. The point where this line intersects the horizontal line through (101) is the position of *b* ($0\bar{1}0$). From this, as a radiant, draw a line through *a* for the prism zone *ba*, and draw lines from *c* through M^1, m^1, by the intersections of which on *ba* produced the true positions of *M* ($1\bar{1}0$) and *m* (110) are found. Rule lines parallel to *ca* through *Mm* to cut *bc*. The points of intersection so found are respectively those of *q* ($0\bar{1}1$), *k* (011); and, on b^1 (101), respectively, those of *z* ($1\bar{2}1$) and *s* (121). From these fixed points the projection of all the rest of the poles of Chalcanthite follows easily enough. For example, *d* (210) is easily determined by drawing lines from (100) to (011) and (110) to (101). A radial from (001) through the point of intersection to the prism zone gives the position required. Similar lines from ($1\bar{1}0$) to (101), (100) to ($0\bar{1}1$) give in like manner τ ($2\bar{1}0$). A line from *q* ($0\bar{1}1$) through *p* (111) to the prism zone gives the position of *h* (120), and from the same *q* through *s* (121) gives α (130). A line from *m* (110) through ($1\bar{1}1$) gives the position of *w* ($0\bar{2}1$) on *bc*; while *v* (021) is determined by a line from *M* ($1\bar{1}0$) through *p* (111) to the zone of *bc*. For (310) the lines from (100) to (111), ($1\bar{1}1$) respectively, are intersected by lines from (110) to ($1\bar{1}1$), ($1\bar{1}0$) to (111). Radial lines from *c* through these intersections to the prism zone give the points required.

For Axinite, the most anorthic of all crystals, a somewhat different mode of working has to be adopted. The tangent plane is best placed so as to touch the sphere of projection at *r* ($1\bar{1}1$). As in the case of Chalcanthite, first rule a perpendicular line through this point, and another at right angles to it, each prolonged both ways to the sides of the paper. Set off *M* ($1\bar{1}0$) and *c* (001) from the first projection by the method previously described. Determine the distance *Mm*, *ma*, *mb*, by the method adopted for the gnomonographic projection of the prism zones in the example given in Part I. From *M*, with the radius *Mb*, describe an arc cutting the right-hand prolongation of the horizontal line through the tangent point. The point so determined is *b* (010), which is of prime importance as a radiant point.. From *b* draw a line through *M* for the prism zone. Set off *Ma*, *Mm* from the

first projection, and draw lines from these both ways through *c*. Beyond this the procedure is the same as that already described.

The Linear (or Quenstedt's) Projection of Anorthic Crystals.—A method of projection much in use amongst crystallographers of the Continental school is that with which the name of Quenstedt is associated. All things considered, it is not so generally useful as the stereogram; but it is undoubtedly a valuable adjunct to that projection, and is useful in many other ways. Moreover, it is easily constructed. A short description of the principles upon which it is constructed may advantageously be given here. The plane of the map is parallel to some one face of the crystal to be represented—usually to one of the pinacoids, and most commonly is parallel to the prism zone. The different faces are represented, not by their poles, but by their respective traces, which are supposed to be of indefinite length, and they are all conceived to pass through the axis perpendicular to the plane of projection at the parametral length proper to the species. As directions, and not magnitudes, are to be represented, every face is supposed to be shifted parallel to itself until it cuts the parametral point referred to. In accordance with this principle, the face *a* (100) is shifted parallel to itself so as to pass through the point in question. So, too, is *b* (010), and *m* (110), and all the faces of the prism zone. Their traces are prolonged indefinitely, as it is the *directions* of the faces that are delineated. The parametral length of *b* is drawn upon the line which represents the *direction* of *a*; and, in like manner, the parametral length of *a* is drawn upon the line whose direction is that of *b*. Next, supposing that the plane of the projection is that of the prism zone, the orthodomes and clinodomes (or macrodomes and brachydomes) have to be drawn in. Taking the unit forms first:—These cut the *a* axis, or the *b* axis, as the case may be, and also the *c* axis, each at unit length, their traces will be at unit distances from the centre of the projection—the macrodomes at the unit length of *a* and parallel to *b*, and the brachydomes at the unit length of *b* and parallel to *a*.

Next we have to consider the pyramids. The unit

pyramid cuts both *a* and *b* at full length, and also *c*. Lines of indefinite length passing through *a* and *b* are accordingly drawn. But there is usually a set of pyramids in the unit zone which cut the vertical axis at a fraction of its normal length, *e.g.*, (112), (223), (334), etc., which cut the vertical axis at a half, a third, a fourth, etc., of its unit length. Now, by the principles of this projection, all the faces must pass through the vertical axis at unit length. We therefore, in such cases, simply multiply all the three intercepts by the denominator of last of the three, converting the first into $\frac{2}{1}\ \frac{2}{1}\ \frac{2}{2}$, the second into $\frac{3}{2}\ \frac{3}{2}\ \frac{3}{3}$, the third $\frac{4}{3}\ \frac{4}{3}\ \frac{4}{4}$. That is to say, in the first instance we take both *a* and *b* at twice the unit length, and the vertical axis at twice half, or, in other words, the whole. To draw the trace of this, we therefore measure twice the length of *a*, and twice that of *b*, and draw lines connecting both points. In like manner, we take one and a half times the length of *a* and of *b*, and three-thirds, or the whole, of *c*, and proceed as before. In the third case we take four-thirds of each, and so on. The same principle is followed in drawing the macrodomes; thus (102), (305), (403), (503) are represented respectively by lines cutting twice the length of *a* and parallel to *b*; five-thirds the length of *a*, three-fourths the length of *a*, or three-fifths, as in the last case. In the case of the brachydomes (012), (023), (021), (032), all those figures are multiplied by the last, and we proceed as usual. The second and fourth examples are taken respectively at one and a half times the length of *b*, parallel to *a*, and two-thirds the length of *b*, and parallel to *a*, and so on.

We might take one or two other cases by way of further elucidation. Suppose it is desired to lay down the trace of (375). In this we have one-third of *a*, one-seventh of *b*, and one-fifth of *c*. *c* must be a whole number. We therefore multiply all three by five, and get 5/3 of *a*, 5/7 of *b*, and one of *c*. These proportions are, accordingly, taken either by the proportional compasses, or, better still, by means of the proportional scale, whose construction was described in Part I. p. 343.

If the drawing is correctly done, it will soon be evident

that a number of the traces intersect at one and the same point, and on studying this relationship by reference to the corresponding stereogram, the reason will be sufficiently evident.

Now a line joining the intersection of any two traces and the centre gives the direction of intersection of the two faces represented; and it is mainly by taking advantage of this principle that the problem of determining the intersection line of any two faces to each other is graphically determined. Indeed, a knowledge of the principle in question is indispensable to any one who wishes to make a correct clinographic (or other) drawing of a crystal.

In making linear projections of crystals belonging to the Monosymmetric and the Anorthic systems, due allowance must be made for the foreshortening of the *a* and *b* axes. But as the method to be adopted has already been described in both the former part and in this, there is no need to repeat the instructions here.

The application of this projection to the clinographic delineation of crystals will be considered at greater length further on.

The Determination of Crystalline Forms.—It is assumed in these papers that the reader, knowing something of Mineralogy, desires to know more, and does not aim, at present, at doing much original work. There are large numbers of people who have to do with minerals who perhaps may never have occasion to do much more in crystallography than to determine accurately some of the commoner crystalline forms on minerals whose species are already known. It is to such as these that the maps previously described are likely to be most useful.

One thing more than another that a student who makes his own maps soon learns, is a knowledge of the zonal relationship of the different forms of each species. Regarding this, I do not for a moment hesitate to state my belief that a thorough knowledge of these maps and their uses is of at least of equal importance to a thorough knowledge of the reflecting goniometer and the uses to which this may be

applied. Given a correct determination of a few of the leading forms of any one of a large number of crystals, the identification of most of the remainder follows easily enough, when once the knowledge of the maps and their uses has been gained.

In the course of an extensive experience in the determination of the crystalline forms in the large collection of Scottish Minerals under my charge here, I have but rarely had need to make use of the fine reflecting goniometer which belongs to the Edinburgh Museum. True, there does now and then arise a case in which I have to deal with crystals of a species which has not been determined. *Then*, certainly, accurate determinations of angles have had to be made, and they could be made only by using a proper instrument like this. But in the great majority of cases, where the species of the mineral under consideration is already known, a much simpler method suffices for the identification of any doubtful forms. First of all, the most essential requisite is a good stereogram of the species in question. (I have now made such of all the crystallised species occurring in Scotland.) This serves, as will be presently shown, as an excellent substitute for the divided circle of the goniometer; and as most of my stereograms are made to five inches radius, it is possible to measure with them to a considerable degree of accuracy. Next, for use with this, I have constructed an arrangement of three stout brass wires, each bent at two right angles, and fitted into hard corks, in such a manner as, when combined together, to form an efficient universal joint, by means of which the crystal to be measured can have any part brought into exact line with the chief axis of rotation, which runs through a hard cork mounted on a heavy stand, and is prolonged some distance beyond. On this prolongation another cork is fixed, which carries a long steel needle, used as a pointer. For use with this is a low-power microscope on a stand, and provided with a considerable range of movement. The whole is placed in front of a mirror which reflects the light of a gas flame about nine feet away. There is no difficulty whatever in adjusting a crystal in such a manner as to bring the edge to be measured over into the

line of axial movement of this instrument. Nor is there any difficulty in working in broad daylight, seeing that the orange-coloured light of the gas flame is seen to be quite distinct from the whiter light of day. There is no difficulty in adjusting the steel pointer to any radial zone on the map corresponding to any known face on the crystal; and, of course, the movement which brings the next face into the reflecting position moves also the pointer to the radial zone, in which lies the second face whose position has to be determined. This somewhat rough, but very simple and effective instrument, usually gives most satisfactory results. Instead of costing many pounds, its total cost need not exceed that of a few pence, and a man must be a very poor mechanic indeed if he cannot construct one like it for himself in an hour or so. Of course, it is not meant for original research, nor is it of much use where the species of mineral under observation does not happen to be known. Furthermore, it is of not much use without a stereogram. All the same, I have done much work with it, as any visitor to the Scottish Mineral Collection can at once see. Well on to a thousand crystals, of many different species, have had their forms determined by its aid; and the drawings made after these determinations are placed in contiguity to the actual specimens, which are all properly indicated, so that visitors may, if they desire to do so, examine both drawing and original at any time, and decide for themselves how far the two agree.

As a worker grows familiar with the physical characteristics of the different forms on each species of mineral, the need for examination by goniometric methods gradually becomes less, and may, with long experience, cease to exist. I know that this statement will be received with incredulity by many persons; nevertheless, it is a fact.

Methods of Drawing Crystals.—In dealing with museum specimens, every curator must know that, in many cases, he cannot, and must not, damage a valuable mineral by chipping a crystal off its matrix in order to measure it. If that crystal is to be determined at all, it is obvious, in such a case,

that it must be done by inspection, with the aid of a good lens, and with maps on more than one projection before one. In some cases I have found three stereograms useful, *a*, *b*, and *c* projections, and one or more gnomonograms, in addition, to refer to for the all-important matter of zones. With aids such as these, and with an eye trained to estimate angles and a hand trained to delineate them, it is not really difficult to make a series of freehand drawings of face after face of the crystal, and to join these one on to the other in the drawing until the whole solid is, so to speak, unfolded into one plane, so as to be like a crystal-net. By this means the planes of symmetry can soon be made out; and if the observer have a good knowledge of the habit of the species under consideration, it ought not to be long before some of the leading forms of the crystal are determined by inspection. Then, a knowledge of the zonal relation of the faces, got by a careful study of the maps, will enable him to carry the determination further; and not unfrequently this may suffice for making a drawing of the crystal itself.

Here, perhaps, is an appropriate place for some observations I have long wished to make upon what may be termed the ethics of crystal-drawing. To a man of science, interested not only in a crystal as a thing of beauty in itself, but as the outcome of a long series of interesting changes in the past, and bearing within itself much which, if properly interpreted, would serve to throw valuable light upon many physical problems of great interest, one would have thought it would be a point of the very first importance to delineate that crystal as exactly as possible. Instead of doing this, the usual practice seems to be to generalise the drawing as much as possible, reducing any inequalities (or "distortions") to which the crystal may have grown, and, generally, they seem to wish to represent it in what people are pleased to call "ideal symmetry." Surely to do this is simply to wipe out evidence which may, sooner or later, lead to the discovery of important principles. Who is to know, in such a case, how much light the abnormal development of one set of faces, as compared with other of the same form, may cast upon some otherwise obscure chapter

in the history of the crystal? Who is to say that we may not some day be able to trace in such features the history of changes of temperature, or of pressure, in the solutions, or the record of some variations, perhaps only slight, in the composition of the solutions, giving rise thereby to important variations in the surface-tensions between those solutions and the growing crystal? Again, how are we to know how much of the characteristics of an individual crystal may be due to solution along one set of planes, or to alternate solution and deposition? There are many other possibilities of this same kind which will immediately occur to anyone interested in crystal-genesis. It seems to me that to draw crystals in "ideal symmetry" instead of as they actually are, is tantamount to deliberate wiping out of the history of the crystal, and ignoring evidence which may some day be of considerable value. In the case of text-book figures, some excuse may be found for this mode of working, because a student needs to have the broader features kept before his eyes, and that in a more or less idealised form. But when a writer has to deal with a particular specimen, formed, perhaps, under very special conditions, regarding which it is desirable to obtain all the knowledge we can, this perversion of the facts seems to me most reprehensible. I wonder what would be thought of a palæontologist who, in figuring, say, a particular specimen of a fossil fish, were to add on fins here, or scales there, to make his specimen look more complete than it actually was? His reputation would soon be lost. Notwithstanding this, one would think, self-evident principle, author after author continues the practice. As examples of what a drawing should be, I should like to instance Mügge's drawings of Greenockite,—*Jahb. f. Min.*, ii. 18 (1882), which anyone who knows the habit of actual crystals of this mineral must at once recognise as faithful portraits. Some day we may know *why* most Greenockites are built up of irregular oscillatory combinations. But the figures usually given do not afford us even as much as a hint that the crystals are generally of this kind.

Let us have portraits of the crystals, with nothing added, nothing essential omitted, and with no attempt at idealisa-

parametral length of the vertical axis, give the direction of intersection of the two faces under consideration.

The methods adopted in making finished clinographic drawings are somewhat complex, and involve a considerable amount of work. Moreover, they do not seem to be at all adequately described in any of the text-books. For these reasons the subject will be treated here at greater length than is usually given to it.

The first step in the process is to construct an axial cross, which shall accurately represent the best possible position in which crystals can be viewed so that their front, right side, and top may all be clearly shown. Various methods may be adopted for projecting this AXIAL CROSS, which, seeing that it forms the basis to all finished clinographic drawings, needs to be made with all possible regard for accuracy. The reader desirous of working out the lines by graphical methods will find these clearly described and illustrated in Dana's "Text-Book of Mineralogy" (new edition of 1898), pp. 547-549, which is reprinted from the older editions of the "System." Even that description leaves a little room for further simplification, which is attempted in the following lines:—Draw a circle of any convenient radius between $2\frac{1}{2}$ inches and 5 inches radius, choosing by preference that scale which is represented upon some good scale of equal parts. As there is usually such a scale of 5 inches on the ordinary 6-inch ivory protractor in a case of instruments, that size, which is not too large for the purpose, may well be chosen. Carefully draw with a fine-pointed pencil two diametral lines exactly at right angles to each other. Mark the point of intersection O, and the right-and-left line BB^1. Extend the vertical line beyond the circle ·047 of the radius, and mark the extremities cc^1. On the circle set off a chord of ·054 of the radius in front of B on the right and behind B^1 on the left. Sign these points respectively b, b^1, and connect them by a diametral line. In the bottom left-hand quadrant set off a chord of ·457 of the radius from B^1, and the same in the opposite direction and quadrant from B. Draw a di and sign the extremities A, A^1. radi on OA, OA^1, and

one particular method. No doubt the clinographic projection is on the whole the best. But often it may serve the purpose better if two, or even three, orthographic views of a crystal are made. It seems to me, for example, in the case of some Calcites, that a basal view orthographically drawn may advantageously accompany a clinographic drawing of the crystal as seen from its sides. In the case of some crystals, Miller's plan of giving two orthographic views is an excellent one. All we really require is that the special characteristics of a crystal shall be shown in the clearest manner possible. One worker known to me, who is perfectly familiar with the methods of clinographic drawing, prefers the orthographic method in general, and especially in drawing orthorhombic crystals, and I can certainly answer for the clearness and generally satisfactory nature of his drawings.

My own method of work in connection with the Scottish Mineral Collection is, first, to make orthographic freehand drawings of each crystal in three aspects, keeping always as near to the actual shape of the specimen, even to its irregularities of fracture, or of attachment, as closely as possible. Then, if a clinographic drawing will show fully and clearly all the special points, one is thereupon made.

Clinographic Drawings of Crystals.—The method of making a finished clinographic drawing is based upon the use of a modification of Quenstedt's Linear Projection, as above mentioned. In this, which the reader will find described in Dana's "Text-Book," 1898 edition, p. 547 *et seq.*, the plane of projection, instead of being drawn in plan, is represented as tilted a certain inclination forward and to the right, and the vertical axis, of correct parametral length, is drawn passing in the plane of the paper through the centre of it. On this, as a basis, all the unit forms and most others of common occurrence in the species represented are carefully drawn. Each face is treated as a plane of indefinite extension, which touches the vertical axis at unit length. The zonal points where the traces of two planes meet on the middle plane of the projection (which corresponds to the plane of the paper in the ordinary Linear Projection) are the points which, when connected by lines with the

parametral length of the vertical axis, give the direction of intersection of the two faces under consideration.

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mark these extremities respectively a, a^1. If these instructions are followed with proper care, as good an axial cross may be constructed thus as by the method described by Dana. It will be observed that in this, as in all other crystallographic measurements, the proportional method is followed—b always being understood to be unity.

The axial cross thus drawn is adapted to the CUBIC, the TETRAGONAL, and the ORTHORHOMBIC SYSTEMS, without any change of inclination of the lines.

Dana's method of adapting the standard axial cross to the RHOMBOHEDRAL System is simplicity itself. It is described on p. 549, *op. cit.* Briefly stated, the method is this:—Extend Oa, Oa^1 to 1·732 ($= \sqrt{3}$ its own length) and mark the extremities A, A^1 as before. Join Ab, bA^1, Ab^1, and b^1A, so as to form a rhomb. Bisect each side of the rhomb, and connect the points at the back and those at the front, and draw lines through the points where they cut the rhomb through the centre. Cancel from the original the line AOA^1 and the angles of the rhomb adjacent, and there is left the clinographic projection of a regular hexagon, with its one vertical and three horizontal axes of reference. All that is needed to adapt this to any particular species is to vary the length of the vertical axis to suit. The vertical axis is denoted by i, the right-and-left axis as k, $-k$. The axis to the right in front is $-l$ (and $+l$ behind), and that to the left in front is h, while its back half is $-h$. The axes thus read, starting from the left and going counter-clockwise: $-k$, $+h$, $-l$, $+k$, $-h$, $+l$.

To adapt the standard axial cross to the MONOSYMMETRIC System, the front-and-back axis has to be altered in both direction and length, and the vertical axis, regarded simply as an axis of reference, is altered in length only—all three of these elements varying with the species. The right-and-left axis b remains constant in both direction and length, which latter is always unity; b therefore coincides with the right-and-left axis of reference under all circumstances. The front-and-back crystallographic axis is inclined to the vertical axis of reference at an angle denoted by β. It is measured *behind* and above. To project this angle, and thus

adapt the standard axis to the monoclinic form, a somewhat complicated method has to be adopted. Call the centre of the cross O, the front-and-back axis of reference A, A^1, the right-and-left axis B, B^1, and the vertical axis of reference C, C^1. On a separate paper draw a line OC. From C, with the radius OC, describe a quadrant of a circle, and with a scale of chords, a protractor, or by other means, set off on this an angle equivalent to β; drop a perpendicular from this point to OC, and sign the intersection d. Set off Od upon the standard, above and below O. On the former paper draw a right angle with sides equal to OA, calling the vertical line OB and that at right angles to it OA. From O, with a radius OA, describe a quadrant of a circle, and on this, from B set off the angle β. From the point so determined drop a perpendicular to OA, and sign the point e. Transfer the distance Oe to the standard on OA. From e draw a line parallel to OC, and from d draw another line parallel to OA. The point of intersection of the two lines so drawn is the true direction and the standard length for the position of the inclined axis projected at the angle β. All that is now required is to adapt this line, taken as unity, to its parametral length proper to the species, and, of course, to adapt the vertical axis of reference, also taken as unity, to its own proper parametral length, as in the case of the other axis.

In adapting the standard axial cross to ANORTHIC species, the three rectangular axes of reference themselves remain unaltered, as in the case of those of the Monosymmetric System. There are now three inclinations to deal with, β measured, in this case, from the vertical axis of reference in the *front*. The method of doing this has just been described. Next the axis b has a double inclination, nearer to, or farther from, the front horizontal axis of reference, and nearer to, or farther from, the vertical axis of reference. The former angle is denoted by γ, and the latter by α. The angle γ is always dealt with first, and the clinographic projection and length of the axis in question is obtained in exactly the same way as that just described. Putting this into language more easily understood by many people, set off on the front horizontal axis of reference OA, $Oa = OA \times \cos\gamma$; and on the

right horizontal axis of reference $ob = OB \times \sin \gamma$. From b draw a line parallel to OA, and from a draw another parallel to OB, and through the point of intersection of these lines, which call D, draw a line DOD^1 to the left. On OD^1 mark off a distance equal to OD, and draw a line through that point parallel to OC.

We have now obtained the skew denoted by the angle γ, but the axial cross so far is only duoclinic, whereas it has to be triclinic. We have therefore now to draw the clinographic projection of the axis last described as further modified by the angle α, which is that which it forms with the vertical axis of reference. Now, therefore, lay off on Oc, $Oc^1 = Oc \cos \alpha$, and from the position of c^1 thus found draw a line parallel to DOD^1, and then a line drawn through the point of intersection and O gives the desired inclination and unit length of the ob axis, which is taken as unity, and has not therefore to be proportioned to be adapted to the parametral length proper to the species under treatment.

Given these axial crosses, the next step is to adapt the principle of the Linear Projection to them. The reader has therefore to conceive that the Quenstedt's Projection, already described on p. 414, instead of being drawn on a plan, is projected so as to pass through the centre of the axial cross, and to be skewed to the left and tilted forward at the same angles as those of the horizontal arm of the axial cross. Upon this, which forms the middle plane of the construction, the elementary forms of the crystal are to be carefully drawn for use as standards. The six pinacoidal faces, and the unit pyramid, as well as other forms of common occurrence, are drawn in. From the principle of construction of this projection described already, it will be not at all difficult to delineate the true direction of the intersection of any two planes in any position of the clinographic drawing. It will probably give a beginner a certain amount of trouble to work the method out for himself, but it is certainly worth while to do so.

In order to illustrate the methods of work followed in the next stage, a description of the steps in the construction of

a few examples to be used as standards may well be given here. Forms belonging to the Cubic System will be taken first. The axial crosses should be drawn on rather thin, good cardboard, and fine pin-holes should be pricked through the chief points in the projection. In using the standard cross, it is laid over the paper upon which the other drawing is to be made, kept in position by weights, and then the points are pricked through with a fine needle, mounted in some kind of holder. The standard is then removed, and a fine ring is pencilled round each of the punctures as lightly as possible. Then these are connected by straight lines. I prefer a hard pencil for this work, which should have a chisel-edge instead of a point, and should be kept fine by rubbing it on a piece of fine glass-paper, and then on a piece of brown paper. I usually prefer to pencil in first the unit octohedron, which is easily done. Next the pinacoids are drawn, so as to project the outline of the cube. This forms a good test of the draughtsman's skill, and the work therefore needs to be as carefully done as possible. When the outline of the cube is quite correct, it may advantageously be carefully inked in with a ruling pen, an undercut straight-edge, and Indian ink. If an ordinary straight-edge is used, it is well to fasten two or three strips of cardboard on the under side, so as to prevent the ink running from the pen to the drawing in larger quantities than is desired. Next ink in the cubic axes in some distinctive colour. This done, divide each edge of the cube into halves, and join the middle points of each pair opposite the centre by lines. These, also, may be advantageously inked in of a different colour from the rest. Then join the opposite solid angles of the cube by lines through the centre, and colour these some distinctive tint also. Call the cubic axes the Tetrad Axes, because a revolution around each of them brings similar faces four times into the same position in one revolution. Call the next the Dodecahedral or Dyad Axes, because a revolution around each of them brings the cube twice similar faces twice into the same position in one revolution. Lastly, call the third set of axes the Octahedral or Triad Axes, because three times in each revolution about one of them the similar faces

are brought into the same position. The first set are normal to the faces of the cube, the second normal to those of the Dodecahedron, and the third normal to the faces of the Octahedron. The first and the third are easily enough drawn; but suppose that we desire to get a standard for the Dodecahedron, the method of procedure is not quite so clear, and is not given in any book I have seen, except in the Rev. Walter Mitchell's "Crystallography," in Orr's *Circle of the Sciences* (1856), from which, in 1863-64, I gained my first insight into that science, and which, nearly forty years later, I value still. The methods given here are somewhat different from his, and are even simpler.

In the case of the DODECAHEDRON, measure off half the length of each of the Triad Axes, and join the points by lines drawn to the extremities of each of the Tetrad Axes, and the figure is drawn. If it is desired to draw a standard for the THREE-FACED OCTAHEDRON, first draw the Octahedron in the customary manner, then measure off from anything more than half to two-thirds of the Triad Axes, according to the form desired, and join these points by lines drawn to the extremities of the Tetrad Axes. Dana records twenty-one of these Trigonal Trisoctahedrons, as he terms them. As example may be given, 40.40.1; 661; 552; 774; 332; 331; 221; 65.65.64. To draw any of the twenty-one forms, measure off from o along the Triad Axes a fractional length of each whose numerator is the first figure of the index, and whose denominator is the sum of all three. Thus for (221) take two-fifths of the Triad Axes, for (332) take three-eighths, and so on. From the points so determined draw lines to the extremities of the Tetrad Axes, and the figure is completed. In the forms known collectively as the TWENTY-FOUR-FACED TRAPEZOHEDRON, sometimes called the Icositetrahedron, Leucitoid, or Tetragonal Trisoctahedron, the second and third indices are equal, and are less than the first. Dana gives twenty-seven of these, ranging from 40.1.1 to 655, 211 being the most common. We will consider how they may be drawn. The Tetrad Axes are all at normal length; the Triad Axes are cut at a fractional length whose numerator is the first figure of the index, and whose denominator is

the sum of all three, *e.g.*, (211), 2/4 = 1/2; (322), 3/7; (433), 4/10 = 2/5, etc. The Dyad Axes are cut at a fractional length whose numerator is the first figure of the index, and whose denominator is the sum of the first and second, *e.g.*, (211), 2/3; (322), 3/5; (433), 4/7; and so on. Lines joining these points with the others complete the figure required. To draw the FOUR-FACED CUBE, otherwise known as the Fluoroid, the Tetrahexahedron, etc., the principle here adopted is much the same. The Tetrad Axes remain at their normal length; the Triad (and also the Dyad) Axes are cut at a fractional length whose numerator is the first figure of the index, and whose denominator is the sum of the first and second. The Dyad Axes are not used. Dana gives a list of thirty-five of these. As examples may be given (210), one of the commonest; 320, 430, 540, etc. In all of these the first index is greater than the second, and the third is o. Lastly, amongst the holohedral forms of the Cubic System is the SIX-FACED OCTAHEDRON, otherwise known as the Hexoctahedron, the Adamantoid, etc. In this all the indices are different, and are greater than o. In drawing this form the Tetrad Axes are taken at their normal length. The Triad Axes are cut at a fraction of their length from o, whose numerator is the first figure of the index, and whose denominator is the sum of all three, *e.g.* (731), 7/11; (432), 4/9; (11.5.3), 11/19; (15.11.7), 15/33; (543), 5/12; (821), 8/11, etc. The Dyad Axes are cut at a fraction of their length from o, whose numerator is the first figure of the index, and whose denominator is the sum of the first and second, *e.g.*, (731), 7/10; (432), 4/7; (11.5.3), 11/16; (15.11.7), 15/26; (543), 5/9; (821), 8/10 = 4/5, etc.

Lines for the common intersections of any two of these forms can usually be made out by reference to a good gnomonogram of the Cubic System. Mine is a quadrant drawn to touch a sphere of five inches radius at (111). This is large enough to afford space for a considerable number—practically all—of the commoner forms; and it is supplemented by a smaller stereogram to five inches' radius, which serves to show the zonal relationships over a larger area of the sphere of projection. In the few cases

where these maps do not suffice, the student will need to project the two sets of faces in the manner already described.

Drawing Hemihedral Forms.—The TETRAHEDRON is drawn readily enough by connecting the extremities of one pair of the alternate Triad Axes, and drawing lines to the pair on the opposite side which alternate with them in position. The TWELVE-FACED TRAPEZOHEDRON, Deltoidal or Trapezohedral Dodecahedron, which is the hemihedral form of the Three-faced Octahedron, can be drawn by means of a modification of the method adopted for its primitive. The Tetrad Axes are cut at normal length. The Triad Axes are cut dissimilarly on alternate opposite sides, so as to limit one three-faced solid at one distance, and on one-half of the axis, and a second alternating with it, at a different distance on the other alternating with it. There are also positive and negative forms, according to how these are placed. One-half of each Triad Axis is cut at a fractional length from O, whose numerator is the first figure of the index, and whose denominator is the sum of all three, and the opposite half is cut at a fractional length from O, whose numerator is the first figure of the index, and whose denominator the sum of the second and third, *e.g.* (κ 221) 2/5 on one half and 2/3 on the half opposite O; (κ 332) 3/8 on one half and 3/5 on the other.

The THREE-FACED TETRAHEDRON, or Kuproid, Triakistetrahedron, Hemitetragonal Trisoctahedron, etc., is derived from the Twenty-four-faced Trapezohedron by the development of one-half of its face and the suppression of the other. According as one set, or the other set, is developed, the crystals are regarded as positive or negative forms, distinguished respectively by a prefixed κ or π. Dana notices 18 forms ranging from (13.1.1) to (322), (211) being of common occurrence. The Tetrad axes cut the middle of each of the opposite longer edges. One-half of each Triad axis is cut at normal length, and the opposite half is cut at a lesser length dependent upon the particular form under consideration. In (211) this is $2/4 = \frac{1}{2}$; in (311) it is 3/5; in (322) 3/7 from O. In general, therefore, the alternate opposite Triad axis is cut at a fractional length from O,

whose numerator is the first figure of the index, and whose denominator is the sum of all three.

The SIX-FACED TETRAHEDRON, Boracitoid, Hemi-Hexoctahedron, or Hexakis-Tetrahedron, is derived from the Six-faced Octahedron by the development of the faces constituting four of its solid six-faced angles opposite the alternate solid angles of the cube in which it is described. Like the other hemihedral forms, it may be regarded as either positive or negative, according to which set of faces is developed. Dana gives the angles of twelve forms, which range from (521) to (11.10.1); (531) has been observed in Boracite. There is one series, regarded as positive, to which κ is prefixed, and the obverse of this regarded as negative, and distinguished by a prefixed π. The Tetrad Axes form the four-faced solid angles. The Triad Axes join the obtuse four-faced solid angles on one side of O, and the acute four-faced solid angles on the other, at distances varying with the form. In (κ 531) the obtuse six-faced solid angles cut the Triad axis on one side of O at 5/9, and on the opposite at 5/7.

The PENTAGONAL DODECAHEDRON, Pyritoid, or Pyritohedron, is a hemihedral form of the four-faced cube, and, like the other hemihedral forms, is regarded as positive or negative, distinguished respectively by κ and π, in accordance with the half set of faces which is developed at the expense of the other half. It is theoretically possible for each Four-Faced Cube to be represented by its corresponding hemihedral form, both positive and negative. Dana gives 32 positive forms, ranging from (κ 10.1.0) to (κ 11.10.0), (κ 210) being a common form. In this form the Tetrad axes join the middle of the opposite six unequal edges. The Triad axes join each of the eight three-faced solid angles, at distances varying with the fundamental form. There are also 12 three-faced solid angles which do not lie in any of the three species of axes belonging to the cube, but which lie in a face of the circumscribing cube, along a line parallel to one of its edges, and at a distance from the Tetrad axes varying with the form, being half the length of the Tetrad axes in κ or π (210), in which also the Triad axes are cut at 2/3 of their length. Generalising, the lines

along the face of the cube are cut at a fractional length of the Tetrad axes, whose numerator is the second figure of the index and whose denominator is the first; while the Triad axes are cut at a fractional length from O, whose numerator is the first figure of the index and whose denominator is the sum of the first and second.

The last hemihedral form of the Cubic System to be noticed is the DIPLOID, which is called also the Dyakis Dodecahedron, and the Trapezoidal Icositetrahedron, etc. It is the hemihedral form of the Six-faced Octahedron. It is represented by both positive and negative forms, denoted as usual by a κ or π prefixed to the index of the fundamental form.

Dana recognises 30 positive forms, ranging from (κ 721) to (κ 543). This form is bounded by 24 irregular trapeziums having only two sides equal. It has six four-faced solid angles which terminate the opposite extremities of the Tetrad axes, and touch the centre of each face of the circumscribing cube. It has also 12 four-faced solid angles, which do not lie in the Tetrad, Triad, or Dyad axes of the cube.

The Tetrad axes join the opposite four-faced solid angles, while the Triad axes join the six-faced solid angles at distances from O equal to those of the fundamental form from which the Diploid is derived.

In adapting the Standard Axial Cross to the other systems, the axes have to be varied in length, and the neat methods which are applicable to drawing most of the simple forms belonging to the Cubic System are no longer available, or else become of too complicated a nature to make it worth one's while to employ them. For the delineation of these, therefore, recourse must be had to the methods described in more detail above, in connection with the Linear Projection.

The usual plan, after the preliminary freehand sketch of a crystal has been made—as nearly as possible in all respects with the same relative proportion of the faces seen in the crystal so drawn—is to redraw it first on a larger scale, taking

the directions of the lines at first by freehand drawing from the pattern; and then to redraw it a third time by fixing the sketch upon the pattern, and ruling the lines with a fine pencil and any convenient arrangement for drawing one line parallel to another. The ordinary parallel rulers are of little or no use for this work. There is no plan so good as that of using a rather-thick steel straight-edge and a good vulcanite set-square. With practice this is far more convenient than any tee-square, or any other of the instrumental arrangements commonly in use amongst draughtsmen. It is well to make the drawing of a fair size, which is not difficult to do by this method. It can easily enough be reduced afterwards by photographic or other processes, or even by proportional compasses. Hot-pressed paper or good thin cardboard are best for the purpose. All the drawings I have put out in connection with the Scottish Mineral Collection are on thin white card.

How to Deal with Doubtful or Undetermined Forms.—It must frequently happen that some one circumstance or another prevents the determination of some form or forms of a crystal under examination. Perhaps it is in a deep cavity, and cannot be got out to be measured; or its faces may be too dull, or too uneven, to afford the requisite reflections, even when coated with black lead or glazed with a thin coating of gum. In such cases it may be possible to make a close approximation to its position, *e.g.*, it may be known to occur in a certain zone, in an undetermined position between two other faces which have been identified. In such a case as this latter, an asterisk placed beneath a bracket connecting the symbols of the two known forms suffices for the purpose. In other cases, where that kind of evidence fails one, and there is no means of identifying the face, a simple asterisk will usually suffice. Where one has to deal with curved faces which obviously bend over from one known face to another also known, a simple dash between the two serves the purpose of denoting the curvature. Thus *t*—*y* would signify that there is a curve from what is known to be *t* to another known to be *y*. Calcite and Gypsum furnish abundant illustrations of what is meant. But with practice

and extension of experience in dealing with the crystals of any given species, the shape of the several faces, or their lustre, or their position between two faces already known, etc., or any of these in combination, will usually suffice for determination by inspection.

Of course, this kind of knowledge cannot be arrived at without a considerable amount of previous work, or without a very full and extensive knowledge of the general habit of the species under consideration; and it must be always borne in mind that one observer may have gained this facility in dealing with crystals of a certain species, or a small number of species, and yet be quite unable at the outset to find his way about the faces of the crystals of a species with which he does not happen to be familiar. To do any really good work in this, as in other lines of scientific work, one must work long over a small number of species, and keep at the work long enough to become more or less of a specialist. I fear that there are, unfortunately, very few even of those who are interested in Mineralogy who are willing to undertake all the labour necessary even to obtain the requisite knowledge of much more than the elements of Crystallography.

XXVIII. *Obituary Notice of Mr James Bennie.* By J. G. Goodchild, H.M. Geol. Survey, F.G.S., F.Z.S.

(Read 17th April 1901.)

It has not uncommonly happened that men who have eventually attained to more or less eminence as geologists have made a start in life under circumstances that might appear to be altogether unfavourable for the development of any scientific turn of mind. Many instances will immediately occur to any one who will give the matter a thought. The subject of this notice was not much more favourably placed in this respect than others amongst those just referred to. A brief sketch of his early career may therefore suffice for the object at present in view.

James Bennie was born in Glasgow in 1821. His health as a child was not very robust, and his parents acted wisely

in not allowing him to waste his time and further impair his health by attendance at school. Doubtless it proved fortunate for him that he was early thrown on his own mental resources, instead of having his wits dulled by that everlasting preparation for examination which usually passes for education amongst those who ought to know better. Be that as it may, the daily labour in which young Bennie was early called upon to take a part left him sufficient leisure to enable him to acquire knowledge, as the need for it arose in his mind. It will probably occur to many people to remark that knowledge gained in this way is of much greater permanent value than any attained by means of cram. Anyway, Mr Bennie never seems to have attained to that dislike to mental effort, which those who are injudiciously helped in early life are afterwards only too often apt to experience.

Like many other natives of the west of Scotland, his attention was soon turned to the records of those past changes of the earth whose effects were constantly before his eyes in his native parts; and it was not long after he reached early manhood that he began to turn his attention to original work of a geological nature. Evidence of this is to be found in the papers, of which a list is appended to this notice.

The Geological Society of Glasgow was founded in 1858, and we find Bennie enrolled amongst its members in the year following. From that date until the day of his death, his interest in the work of that Society never flagged, and he soon came to be regarded by its members as one of the most esteemed of the band of energetic and enthusiastic brethren of the hammer, of which that Society has always consisted. Bennie was always greatly interested in the records of past changes of life upon the globe, and never could be got to take much interest in that "lifeless geology,"—as Horace Woodward terms it,—whose devotees devote themselves so exclusively to the study of bits of rock, as to lead to the present phase of geological activity being aptly termed the "Stone Age."

Bennie's enthusiastic study of fossils, and his aptitude as

a collector, soon attracted the notice of the officers of the Geological Survey, and when it was in contemplation to enlarge the staff of that body, in 1867, Bennie was eventually prevailed upon to join the Survey as a fossil collector—a post which he held until he left the service, a short time before his death.

While on the Survey he collected a very large number of specimens, chiefly of fossils—though his Survey duties required also that he should devote his attention, at times, to the less congenial task of collecting rock specimens. The extent of these collections can only be fully realised by those who, like the present writer, have had Bennie's collections through their hands. In the course of his official work, he, directly or indirectly, contributed much to the advancement of geological science, and, of course, especially so in connection with fossils.

Mr Bennie's chief work, for a long time before his retirement from official service, consisted in searching both ancient and modern sediments for minute traces of life. Year after year, those who knew Bennie would commonly find him plodding to or from some newly-exposed section, from which organic remains were to be obtained. His bags, on these occasions, were usually very full, and his general aspect suggested long contact with mother earth. When not engaged in collecting, he would generally be found plodding, with equal patience and industry, at the washing and general preparation of his gatherings; or going over them afterwards, with a lens in one hand and a mounted bristle in the other, picking out micro-organisms from the material spread out upon an old slate. Large quantities of material for other workers were sorted out in this way, and many a scientific worker is indebted to James Bennie for help that would, but for his exertions, have been almost impossible to obtain. In addition to this he left much unused material, which still awaits examination.

In 1875 Mr Bennie joined the Royal Physical Society, and he remained, up to almost the time of his last illness, one of the most regular attendants at the Society's meetings, and one of its staunchest supporters, not only by his presence and his literary contributions, but by his subscription. To

his honour be it told, out of his small salary as a fossil collector, he regularly paid a guinea per annum, leaving the balance, over and above the annual subscription, in the hands of the treasurer, as his contribution towards the funds of the Society. Of how many members can it be said that they have done the like?

He was also an honorary member of the Edinburgh Geological Society. After doing many years' useful work in connection with geology, Bennie was awarded, by the Geological Society of London, with the Murchison Fund.

On account of Bennie's zeal and enthusiasm in connection with his official duties, many of his colleagues often expressed the wish to keep him in their midst as long as possible, and for this reason an exception was made in regard to the age limit for compulsory retirement from the service. Even when no further extension of service was any longer possible, and Bennie had, nominally, to retire, on a pension, his numerous friends would usually find him still hard at work, as usual, in his accustomed spot at the Survey Office; and there he held out until failing health really obliged him to stay at home. Then, as might have been expected, he quietly passed away, leaving behind him an honoured name, and the affectionate regard of a large circle of his fellow-workers in science.

LIST OF PAPERS BY MR BENNIE.

Drawn up by Mr A. Macconochie, H.M. Geological Survey.

1865 Bennie, James, On the Surface Geology of Glasgow, *Trans. Geol. Soc. Glas.*, vol. ii. p. 100.

1867. ——— Further Observations on the Surface Geology of Glasgow, *Trans. Geol. Soc. Glas.*, vol. ii. p. 260.

1868. ——— On the Surface Geology of the District round Glasgow, as indicated by the Journals of certain Bores, *Trans. Geol. Soc. Glas.*, vol. iii. p. 133.

1883. ——— The Glaciated Summit of Allermuir, *Proc. Roy. Phys. Soc. Edin.*, vol. vii. p. 307, 1883.

1885. ——— Note on the Contents of Two Bits of Clay from the Elephant Bed at Kilmaurs in 1817, *Proc. Roy. Phys. Soc. Edin.*, vol. viii. p. 451.

1886. Bennie and Kidston, On the Occurrence of Spores in the Carboniferous Formation of Scotland, *Proc. Roy. Phys. Soc. Edin.*, vol. ix. p. 82.

1888. ——— On the Prevalence of Eurypterid Remains in the Carboniferous Shales of Scotland, *Proc. Roy. Phys. Soc. Edin.*, vol. ix. p. 499.

1888. ——— The Redemption of Sandstone Quarries, *Trans. Geol. Soc. Glas.*, vol. viii. p. 298.

1889. ——— On Things New and Old from Cowdenglen, *Trans. Geol. Soc. Glas.*, vol. ix. p. 213.

1889. ——— and Thomas Scott, The Ancient Lakes of Edinburgh, *Proc. Roy. Phys. Soc. Edin.*, vol. x. p. 126.

1890. ——— Note on a Recent Exposure of a "Washout" of Strata in New Redhall Quarry, *Proc. Roy. Phys. Soc. Edin.*, vol. x. p. 392.

1891. ——— Scenes and Sections in Thornton Quarry, East Kilbride, in 1868 (read in 1891), *Trans. Geol. Soc. Glas.*, vol. ix. p. 276.

1892. ——— and Andrew Scott, The Raised Sea-Bottom of Fillyside, *Proc. Roy. Phys. Soc. Edin.*, vol. xi. p. 215.

1893. ——— and Robertson, The Raised Sea-Bottom of Fillyside, with Lists of Foraminifera and Ostracoda, *Proc. Roy. Phys. Soc. Edin.*, vol. xii. p. 26.

1893. ——— and Andrew Scott, The Ancient Lake of Elie, *Proc. Roy. Phys. Soc. Edin.*, vol. xii. p. 148.

1894. ——— and Johnstone, Remarks on Two Transverse Sections of Carboniferous Wood from Baberton New Quarry, Midlothian, *Proc. Roy. Phys. Soc. Edin.*, vol. xii. p. 359.

1894. ——— Arctic Plants in the Old Lake Deposits of Scotland, *Ann. Scot. Nat. Hist.*, January 1894.

1894. ——— Possible Arctic Plants in Ireland, *Irish Naturalist*, 1894.

1894. ——— On the Occurrence of Peat with Arctic Plants in Boulder Clay at Faskine, near Airdrie, Lanarkshire, *Trans. Geol. Soc. Glas.*, vol. x. p. 148.

Chapter by Mr Bennie, On the Geology around Elie, in Chapman's *Hand-Book to Elie and the East of Fife*, 2nd Edition, 1892. Elie and Leven, John Purves.

1896. ——— Arctic Plants and Apus Remains at Kirkmichael, in the Isle of Man, *The Naturalist*, August 1896, p. 244.

XXIX. *Notes on the Habits of Malayan Phasmidæ, and of a Flower-like Beetle Larva.* By NELSON ANNANDALE, B.A.

(Read 19th December 1900.)

A PHASMID (*Lonchodes* sp.).[1]

Appearance.—The body and limbs of this Phasmid, which reaches a length of nearly four inches, are of a uniform dull red, except that there is a black spot on each joint of the limbs. The eyes and antennæ are black. There are no wings. The appearance of the living insect bore a pronounced general likeness to that of a fine twig; but there were no resemblances to thorns, liverworts, or other adventitious growths upon its body.

HABITS AND ATTITUDE.

Habits.—During the first week in May 1899, which the "Skeat Expedition" spent in a clearing at the height of about 2000 feet above sea-level on the Nawnchik slopes of Bukit Besar (the Great Hill), I was enabled to see a large number of specimens of this species amid their natural surroundings. I invariably found them standing upon the upper surface of certain broad leaves such as abound in neglected hill clearings, especially on those of the wild banana (*Musa*), exposed to the full blaze of the mid-day sun. The insects did not lie along the mid-rib of the leaf in the characteristic Phasmid attitude of rest, but stood upright, the body being supported on the bent limbs at the height of about an inch above the surface of their resting-place. In this position the red coloration of the insect made it very conspicuous from above, against the pale green of its support; while even from below, its shadow was perfectly visible through the translucent tissues of the leaf. So much so, that when looking for specimens I always examined the under side of banana leaves, and if the shadow was there,

[1] The species, which is not represented in the British Museum collection, is probably new.

took measures accordingly. It would have been quite impossible to mistake the shadow for that of a stick; no stick has six little twiglets arranged symmetrically round it and supporting it wherever it may chance to fall.

Except for slight movements of the antennæ, the Phasmids remained quite still on the leaf; I was never able to see them feed. If they were disturbed in any way, however, they immediately dropped to the ground and made their escape among the long grass and undergrowth. They were able to walk with considerable speed, though their gait was awkward and stilted. I was quite unable to discover what became of them at night, for I never found them on the leaves either late in the afternoon or early in the morning. Most probably they remained concealed among the undergrowth except during the heat of the day. The only specimen which I obtained away from the clearing on Bukit Besar was captured on the ground in deep jungle, one morning in the beginning of September. Even on the jungle floor it was not very inconspicuous, as its colour was too uniform, and it betrayed itself completely by walking about at its fastest speed.

Remarks.—There are many animals which might be said to be protectively coloured, were they found habitually among the objects that they resemble. For instance, the larva of a common Malayan bug (*Mattiphus* sp. (?)) is flat and somewhat leaf-like in shape, and in colour harmonises exactly with the peculiar pink of the young leaves of many seedlings. Sometimes a specimen of this larva chances to stray among such leaves, and then appears to be protectively coloured, being very hard to detect, by the sense of sight only, in such surroundings. But its usual position is on stones, and in other situations in which it is conspicuous. It is an active insect, provided with well-developed stink-glands, and has apparently no need to conceal itself, supposing that it were possible for it to do so. Its likeness to the leaves is, it seems, a chance one, and has no bearing, as far as we can see, on any theory in particular. The Phasmid, however, is only conspicuous at certain times of day, when the sun is at its hottest and

brightest. Possibly it is sensitive to change of temperature or moisture, but this does not seem to be the ultimate reason for its disappearance. At mid-day the mammals, birds, and amphibians of the jungle are at rest. They are not asleep, but they do not search actively for food, nor come out of the wood into the clearings. Now Wallace points out that the stomachs of insectivorous birds, especially of forms allied to the cuckoos, some species of which are very common in the jungle of Lower Siam, are often filled with Phasmids. Lizards, of course, are generally most active when the sun is hottest; but in these hill-clearings reptiles of all sorts are rare. In the buffalo lawns of the plains of the Malay Peninsula, Phasmids are not plentiful, or, at any rate, are not often seen.

I have a certain amount of negative evidence that the majority of Malayan Phasmidæ are most active in the middle of the day, being inclined to remain concealed in the early morning and late afternoon. In the clearing on Bukit Besar three species of the genus *Necroscia* were common, and when the grass and ferns in which they lived were disturbed at mid-day they would flutter about almost like moths, displaying their pink-and-green or yellow-and-black wings to the full. Numerous paired couples of *N. roseipennis* might also be found on the leaves of shrubs and grass.

Too late or too early in the day, it was impossible to see a single stick-insect in the clearing; and during my six months' stay in Lower Siam, I never was able to discover any Phasmidæ of any species late in the afternoon. The only individual which I found in the early morning was clinging to a blade of grass, with its front legs stretched out rigidly in front of its head, and the other two pairs lying close along the body, the second pair directed forwards and the third backwards. The curious paired process which terminates the abdomen in the genus to which this individual belonged (*Myronides*) was clasped round the stem of the grass, so as to conceal the junction between animal and plant and make it more perfect. In this attitude the Phasmid might almost have been taken for an enormous Geometrid larva, but the angle which it formed with the

stem was very small indeed. The stick-insect remained absolutely still while the grass was broken off. Winged Phasmids occasionally take up this position when disturbed; but as a rule they prefer to run away, or, if they are seated on a plant, to drop to the ground or take to flight.

A Flower-like Beetle Larva (apparently one of the Endomychidæ [1]).

Appearance.—The largest specimens were less than a quarter of an inch in length. The head is small, and the body flat and broad, somewhat bug-like in shape. A series of lateral projections runs along each side. In life the insect was completely concealed beneath a number of white filaments, apparently of a waxy nature, which rose from minute papillæ on the dorsal surface. They were rigid, very brittle and fragile, more so even than like structures on certain of the Homoptera. Most of them were about an eighth of an inch in length, but near the middle of the abdomen there were generally two which were at least twice as long as the others. These filaments stood upright, at right angles to the main axis of the insect's body. The legs were slender and short, but they were evidently well adapted for running. Seen in profile, the larva bore a ludicrous resemblance to a miniature hedgehog, an animal which was also suggested by its gait.

Habits.—The larva is common in Patalung and in Nawnchik. (My observations were made in April at Ban Kong Rah, a village in the hill country of Patalung, and confirmed later on Bukit Besar.) During the heat of the day it is extremely active, running about on the leaves of a Zingiberaceous plant which grows near the edge of the jungle and reaches the height of from four to six feet, and from which the larva probably obtains its food. At this time the insect bears a strong likeness to a small white

[1] Very little is known about the larvæ of this family, most of which are exotic; but my specimens resemble the larva of the British species, as figured by Westwood, closely. The latter are found in a web-like structure, which may be the dorsal filaments of this Malayan species.

composite flower impelled by some such external force as a light breeze, for the legs are completely concealed beneath the dorsal filaments. Should the plant be interfered with in any way while the insects are active, they will immediately drop to the ground (from which the fragility of their dorsal filaments makes it almost impossible to lift them) and run towards the nearest long grass, among which they hide themselves.

Early in the morning, as late as two hours after sunrise (which occurs in Patalung between five and six o'clock), the larvæ may be found resting motionless in the angle formed by the leaves with the stem of their favourite plant—never more than one of them being in the same angle. At this time of day the whole plant may be pulled up by the root, and carried for some little distance, before they are sufficiently aroused to drop off. In just this position there is in many plants which grow near the edge of the jungle, in Patalung and Nawnchik, a bunch of coarse white hairs, finer in texture than the filaments on the beetle larva, but sufficiently like them for one to suppose that the insect simulates them while at rest. These hairs are not present in any of the ginger-worts, but they are well developed in many grasses that grow in the same environment.

The only specific flower which this larva may possibly simulate, in its times of activity, is a kind of groundsel which is common in the places where the insect is found. The flower is larger than that of the British species, but otherwise very similar to it, except that it is either pale mauve or white in colour instead of being yellow. I do not think, however, that the beetle larva simulates any particular flower. I have never found it associated with the groundsel in any way.

Remarks.—The hour immediately preceding and following upon sunrise is the time of the greatest activity of many Malayan animals, for both nocturnal and diurnal species are often then at work. However, nothing being known as to the enemies and dangers to which this particular insect is exposed, nothing can be regarded as proved as to the reasons of its rest in the early morning. The position which it

occupies is one well sheltered from rain or dripping moisture: so far as my observations go, it never rests on the base of the highest leaves of a plant.

XXX. *Note on a Living Specimen of* Galeopithecus volans. By Nelson Annandale, B.A.

(Read 20th February 1901.)

A female specimen of *Galeopithecus volans*, with a newly-born young one, was brought me about the middle of April in Patalung, Lower Siam. The animal, which appeared to be uninjured, was placed in a large poultry-crate, in which it hung, back downwards, from whatever surface chanced to be uppermost, using both pairs of limbs in so doing. The tail was carried arched inwards, in such a way that the membrane attached to it formed a kind of pouch, within which the young one, which was almost naked, clung to the hair of the abdomen when not sucking. The tail was straightened during the evacuation of the fæces. If disturbed from its habitual resting-place, the young animal crawled over the body of its mother, squeaking feebly. The bright pink colour of the naked skin of the ears[1] and palms, noticed by Captain Flower, was very conspicuous in the adult but quite absent from the young specimen, which was of a yellowish flesh-colour.

For the first two days of its captivity the female refused to eat, although bananas in their natural state were repeatedly offered to it; afterwards it eagerly licked cocoa-nut "milk" and rice-water from my finger. When a peeled banana was held in front of its mouth, it licked the fruit so vigorously, its tongue being very strong, that a considerable part of the pulp was expressed. It then drew the flattened tip of the banana into its mouth (which was never widely opened, and during the process of feeding was kept as nearly closed as might be) with its tongue, so that most of the food passed through the openings in the incisor teeth of the

[1] *Proc. Zool. Soc. London*, 1900, p. 338.

lower jaw, which bite against a leathery pad in the upper. It afterwards devoured several other bananas and pieces of green cocoa-nut in the same manner. Though it made no attempt to drink from a vessel placed beside it, it preferred its food to be moistened. It did not use its feet in eating.

The chief natural food of *Galeopithecus* probably consists of the leaves of trees, which contain coarse and indigestible fibres; but the Malays and Siamese agree in accusing it of robbing their orchards, and in saying that it is especially fond of the fruit of the *Langsat* (*Lansium domesticum*). Insects certainly do not form the bulk of its food. Now, the semi-cultivated fruits grown by the Malays and Siamese are notorious for the number or size of the seeds which they contain, and in many cases, such as that of the *Langsat*, for the difficulty with which the edible pulp is fully separated from the inedible residue. My suggestion is that the pectinate teeth of *Galeopithecus* function very much in the same manner, though for a diametrically opposite purpose, as the baleen of the whales; that they act as a strainer by means of which fibres and seeds are prevented from entering the alimentary canal of an animal whose nearest relatives are adapted for an insectivorous diet. I did not see my specimen using its teeth for combing its hair, or for any other purpose.

Galeopithecus is rare in the Siamese Malay States, but common farther south in the Malay Peninsula. Its Siamese name, "*bŏng*" or "*bŏ̆ng*," is evidently a shortened form of the Malay "*kūbŏng*"—a term which includes not only *Galeopithecus* but also the flying-squirrel, *Sciuropterus*, the tree-shrew, *Tupaia*, and even (probably through ignorance in those who use it) the lizard *Draco volans*. But Cantor states that the last is called "*kubin*."

XXXI. *Zoological Names and Theories of the Malays.* By NELSON ANNANDALE, B.A.

(Read 19th December 1900.)

During six months spent among the natives of the Siamese Malay States,—in that part of the Malay Peninsula least affected by the civilisations of el Islam and the West,—I became interested in the stories which were told me about animals, and in the names given by the Malays to those beasts with which they were familiar. I do not refer to the zoological conceptions of the learned Mohammedans who may be found in most Malayan towns, and who appear to derive many of their ideas[1] on matters biological through the Saracen philosophers from Aristotle, but to those of the *ōrăng rayăt*, or "subject folk," of the country villages, men whose profession of el Islam is but the flimsiest of cloaks. Two points especially seemed remarkable to me—(1) the extraordinary resemblance between their zoological folklore and that with which I was already familiar in the Faroe Isles and on the south coast of Iceland; and (2) the amount of sound observation to be detected in many of their most ridiculous tales and names. True facts were there, but buried beneath mountains of the wildest theory—theory which would have put to shame the most empirical of white zoologists. The existence of this solid foundation for their zoological beliefs was all the more remarkable, as the Malays, contrary to popular opinion, are not a jungle-loving race. They hate and loathe the woods, as the abode of all manner of malicious spirits, evil beasts, and deadly diseases; but they appear to have a profound, and almost instinctive, knowledge of the habits of the jungle-dwellers, derived partly from the tradition of their fathers, and partly, no doubt, from intercourse with the Sakais, or aboriginal inhabitants of the country, little timid black savages, who live on what they can kill and find. Mohammedanism, by strictly limiting the number of animals which may be eaten, has removed the most

[1] See "Malay Magic," p. 22.

powerful incentive which a savage can have to the study of natural history. Among the Malays, the hunter is looked upon as a magician (*pāwăng* or *bōmōr*); there are deer magicians, crocodile magicians, and even jungle-fowl magicians, each of whom has made a special study of the habits of the animal which he hunts, as well as being versed in the proceedings of magical wood-craft generally—such as the correct methods of appeasing spirits offended by trespass, of cajoling and subduing the "soul" of his quarry, and of driving out from its body the "mischief" that belongs to all living things and manifestations of nature:

> "O Mischief, Mother of Mischiefs,
> Mischiefs One Hundred and Ninety
> I know the origin from whence you sprang.
> The mischief of an Iguana[1] was your origin,
> The Heart of Timber was your origin,
> The Yellow Glow of Sunset was your origin,
> Return to the places whence ye came,
> Do me no harm or scathe."[2]

I.

With regard to the similarity between the zoological folklore of the Malays and that of the northern Scandinavians, it is not my purpose to say very much. Students of folklore are aware that the conceptions of primitive races are very similar all over the world; and in noticing the likeness between those of the Siamese Malay States and those of the islands of the north-west seas, I am only remarking on this world-wide relationship. When an epidemic of small-pox is raging in Malaya, men think it well to talk of the disease as *săkĭt ōrăng baik*, the "good person's illness": in Gaelic a common euphemism for small-pox is "the good woman."[3] It is well known how the Siamese reverence a white elephant, and how fortunate they consider themselves to capture one—I am speaking of the Siamese country folk, and not of the "highly civilised" citizens of Bangkok. The Faroemen think

[1] *I.e.*, the monitor, *Varanus*. In the original the word is *Bĭawăk*.
[2] Malay charm, translated by W. W. Skeat, "Malay Magic," p. 177.
[3] See Campbell, "Superstitions of the Scottish Highlands," p. 237.

themselves almost as fortunate when they kill an albino pilot whale, or the islanders of the Vestmanna-eyjar when they catch an albino fulmar—a *Fýlakongr*, or "Fulmar king," as they call it. When a Malay magician kills a crocodile,[1] he tells his quarry that he—the slayer—is King Solomon, the "soul" of the beast trembles and submits. An ancient Egyptian crocodile charm[2] has been preserved, which runs as follows:—

> "Thou art not above me—I am Amon.
> I am Anhor, the beautiful slayer.
> I am the prince, the lord of the sword.
> Raise not thyself—I am Mont,"

and so on. A Mohammedan hero, or one who passes as such, has taken the place of Egyptian deities in the modern incantation, but the sentiment of the two charms is identical.

These few instances will illustrate the resemblance to which I refer. There can be little doubt that in some cases it is the result of independent evolution, but in others it arises from historical intercourse. Occasionally it is even possible to trace the connection. For example, we may compare the Malay legend of the *Būrŏng Chrăndăwāsīr* with that of the *Paradisea apoda* of Linnæus, knowing that both[3] originated in the practice of cutting off the legs from skins of the birds of paradise which were sold by Papuans to Malay traders, who in their turn sold them to Europeans.

The *Būrong Chrăndăwāsīr*, or "Bird of Heaven," is said to have marvellously beautiful plumage, and to live in the skies, but to be devoid of feet. It is believed that its eggs drop down from the upper reaches of the air, and, according to the theory of some Malays, the young birds hatch ere

[1] "Malay Magic," p. 299.

[2] *Pap. Mag.*, Harris, viii. 5. Quoted in "Life in Ancient Egypt," p. 353.

[3] These names and legends may be compared with the name given by the fowlers of the Vestmanna eyjar to the Little Auk (*Alle alle*)—*Halkjon*, and with their belief that this bird, which does not breed so far south as the south coast of Iceland, builds a floating nest of its own feathers. In this case the name and legend have been transferred to a different bird from that to which they originally belonged; but, as in the case of *Burong Dewata*, it is still possible to trace a geographical connection, for the Icelanders pride themselves on their classical knowledge even at the present day.

they reach the ground. But in the Siamese States it is usually fabled that the eggs actually fall on to the earth, and that there they give origin to a peculiar snake—the *Ūlār Chĭntōmānī*—which has a duck's head and the voice of the "child of a duck." The *Chintomani* snake turns into the rhizome of a fern called *Pokoh-paku Chintomani* (*Chintomani*, "Nail-plant or Fern"), and the rhizome is made into "lucky" walking-sticks. I have seen one of these: it was mottled like a snake's skin. It is said that whoever finds the *Chintomani* snake will become a great man.

The following is Ambrose Pary's[1] account of the *Manucodiata*, or "Bird of Paradise":—"Jerome Cardan states, in his treatise 'De Subtilitate,' that a bird called *Manucodiata* —that is, in the speech of the Hebrews, the 'Bird of God'— is sometimes seen in the Moluccas, either lying dead on the ground or floating on the water: it is never found alive. . . . (The feathers) which clothe the top of its head are of a golden hue, those on its neck like the feathers of a duck, but the plumes of its wings and tail are like a peacock's: it has no feet. And so, if any weariness or need of sleep overcomes it as it flies, it rolls and twists its feathers round the branch of a tree, and thus suspends its body. . . . It lives on air, and on the dew it quaffs, alone. The male has a depression in his back in which the female incubates the eggs."

But for the different theories invented to account for the oviposition of a footless and entirely äerial bird, the two stories bear a natural and an actual resemblance to one another. Malays who have travelled are quite aware that the bird of paradise is the real *Būrong Chrăndăwāsĭr;* and the great French surgeon's figure leaves no doubt as to the bird he called *Manucodiata*—a name which is itself a curious corruption of the Malay *Būrong Dewata*, or "Bird of the Gods."

The story of the *Maiwās*—the Mias, wrongly called the orang-utang, of Borneo—may be compared with that of the Bird of Heaven, as both are concerned with exotic animals.

[1] *Opera Chirurgica*, lib. xxii. p. 762.

The *Maiwas*, according to the Malays of the Siamese States, is a *brōk* (their name for the cocoa-nut monkey, *Macacus nemestrinus*) which eats men and is as big as a rhinoceros. Its forearm is sharpened like a jungle knife, and formed of the finest steel: with it the beast cuts its way through the jungle. A magician of Patani assured me that on Gunong Taban, a great and somewhat mysterious mountain on the borders of Pahang and Kelantan, the *Maiwas* stands on guard between two cooking-pots, containing respectively the "parent of silver"[1] and the "parent of gold."[2] The tale has an Arabic flavour; but all Malays, though many declare that the *Maiwās* is a *hăntū* or spirit, are agreed that it inhabits the unexplored jungles of the interior of the peninsula—as possibly it may. Confusion often arises, however, between the *Maiwās* and the *Mā-wā* or *Wā-wā*—the gibbon *Hylobates lar*.

The legend of the steel forearm arises from the great strength of this part of the body in the orang-utang, and in its action as the beast forces its way through matted jungle; for, whether there is or is not a great anthropoid ape at present living in the interior of the Malay Peninsula, constant intercourse has existed, ever since the Malays became a wandering race, between the people of the mainland and those of the archipelago. It is, moreover, a fact that some of the best *kris* blades are made from the iron of "*tūlăng maiwās*" or "*Maiwas*' bones," which are in reality the mining implements of some civilised race who sought for tin at one period in the Malay Peninsula. Their workings, in which the *tulăng maiwas* are found, are attributed by the Malays to Siamese of the olden times; and little clay tablets,[3] impressed with the image of Buddha, which are often found in caves near these workings, appear to be either Siamese or Burmese in design; but the modern Siamese themselves disclaim all knowledge of these tablets, and it has recently been pointed out that they have no knowledge of mining except what they have gained in late years from white men. One

[1] *Hību pĕrāk.* [2] *Hību mās.*

[3] These are associated in popular legend with the *orang Pārai* or Peris.

of our Malay servants bought a portion of a *tulang maiwas* for several dollars in Kelantan: it was an iron implement not unlike an ordinary mason's chisel in shape. The Raja Mudah Jering told us that within his own memory a skull of the *Maiwas* had been dug up in his state.

But neither the legend of the *Maiwas* nor that of the "Bird of Heaven" is typical of Malay zoology, for both deal with animals which few Malays have seen alive or in the flesh. Far more interesting, from a true zoological standpoint, is the story of the *Ular Rĭbū-Rĭbū*, a worm of the genus *Gordius*, which is found, at one stage of its existence, in small streams and puddles of water at the roots of trees. It owes its name to the extraordinary resemblance that it bears to a piece of the fine creeping rhizome of the fern *Lygodium*, called *Pōkōh-Pākū Rĭbū-Rĭbū*—the "Fern with Thousands" of coils or fronds, which twines on tree-trunks and similar supports. The worm is said to turn into this fern: it is also said to be the "child" of a large green Mantis named *Ūlăt Sĭdī-Tĭdōr*, the "Sleeping Saint" Grub,[1] and an earthworm which leaps out of his burrow at night to welcome her. The story would be meaningless did we not know that Gordiid Nematodes frequently are parasitic in the abdomens of Mantises, whence they issue upon reaching maturity. At Cambridge there is a specimen from Borneo of *Gordius ornatus* actually issuing from the Mantis *Rhombodera basalis;* at South Kensington a similar specimen, both host and parasite belonging to different species (*Gordius verrucosus* and *Hierodula bioculata*), from West Africa; and in the Hope Department at Oxford there is a third, in which the worm was seen to come out. Under these circumstances, what appears at first sight to be a mere collection of impossibilities becomes a piece of close observation vitiated by wild imagination.

We have already seen two instances in which an animal was supposed to turn into a plant which it resembled. Examples of the contrary transformation are even commoner.

[1] This is one translation of the name; another, given me by a Perak Malay, is "Lazy Sleeping Grub."

It is not surprising that the extremely flower-like pupa of the Mantis, *Hymenopus bicornis*,[1] named in Kelantan the *Kănchŏng*, is believed to be "a flower which has become alive," and to have its origin from the "Straits Rhododendron" (*Melastoma polyanthum*), to the blossoms of which it bears so close a resemblance. It is less obvious why *Heteropteryx dilatata*, a large flat Phasmid, not particularly leaf-like in appearance, should be supposed to spring from the leaves of the Jack-fruit tree (*Artocarpus integrifolia*); but the Malays say that the insect is always found upon this tree, and only eats its leaves. *Heteropteryx* is a rare insect, and is much sought after by the Siamese, who believe that its hard red eggs, when worn like jewels, or, as the Malay phrase is, like "gecko's eyes" (*mātā chīchāk*), in a finger-ring, protect their owners from all manner of ghosts and evil spirits.

When a white zoologist is solemnly informed that a certain hairy caterpillar habitually turns into a squirrel, he seems to have reached the height of absurdity; but a glance at the caterpillar, which is called *Ūlăt Sĕntdāū*, and probably belongs to the Lymantriidæ, will show him the origin of the belief: just behind the insect's head he will notice two tufts of hair longer than that on the rest of the body, and bearing a most ludicrous resemblance to the tufts on the ears of a squirrel. There is a fish not uncommon in the Malay Peninsula which is believed by many to turn into a monkey: a most respectable, and, in the ordinary dealings of life, a most trustworthy old Malay *haji*, told me that he had seen the metamorphosis in the course of completion. Doubtless there is some fancied likeness in the head of this fish to that of a monkey, and it is just possible that the old man had seen one of those Japanese "mermaids" that are formed out of the skin of a monkey and the skin of a fish patched together.

A very strange transformation, according to some Malays, is that of the *Rājā Ānī-ānī*—the "King" or "Queen of the Termites"—which by day rules over the termites in their

[1] See *Proc. Zool. Soc. London*, December 1900.

nest, and wanders forth at night in search of food, burning a path in the grass wherever it goes. To catch it,[1] one must dig a hole in its path before it returns, and place a Chinese teacup in the hole: it will fall into the pit, and be unable to recover itself. If it is kept shut up with grains of raw rice it will grow harder and harder, feeding meanwhile on the rice, until it becomes a stone. In this state it is considered a very powerful charm. I bought a specimen in Kelantan for a dollar: it was a little round pebble of quartz, and was said to have been dug out of a termite-hill in Legeh by the son of a *penghulu* or headman. As a matter of fact, the queen termites are very difficult to find after they have once founded a colony, though in their winged state they are sometimes very numerous; I have demolished many nests without discovering the royal chamber on more than one occasion. Becoming enormously distended with eggs, the female white ants are sluggish in their movements, and almost translucent in colour; indeed, their appearance is not altogether unlike that of a piece of clouded quartz. Apparently the Malays consider that they become hardened into stone by feeding on the hard rice grains. The rice enclosed with the specimen I bought in Kelantan was all nibbled, as if by some small animal; perhaps, in reality, by the Perak trader who sold it to me. There was no doubt, however, that many of the natives really believed the story, as I only discovered by chance that the trader had the specimen.

Many animals are believed by the Malays to have originated from human beings: for example, the deer[2] is said to have once been a man who died of ulcers, the marks of which can still be seen upon its legs. Such transformations are usually attributed to the larger mammals and birds, but the legend of the stick-insect[3] may be taken as typical of this class. Once upon a time a woman was cooking yams. Her husband replaced these yams by stones, and went off to

[1] *Oxford Magazine*, October 24, 1900.
[2] "Malay Magic," p. 171.
[3] "Malay Magic," p. 200.

fetch a cocoa-nut. As he climbed the cocoa-nut palm, he kept calling out, "Are they cooked yet?" ("*Māsāk bĕlūm?*"); and she replied, "Have you climbed it yet?" ("*Pănjăt bĕlūm?*"). Thus they went on wrangling, until they were both turned into stick-insects, which still cry "*Bĕlūm-bĕlăm!*" in the jungle at night. Of course stick-insects do not call out "Belum-belam!" though this exclamation is given them as a name; but some sound of the kind appears to be caused by the stems of the Malacca cane (*Calamus scipionum*) being blown against one another in the wind; and the stick-insect, whose common name, in the Siamese States at any rate, is *Hăntū Sĕmămbū*, or "Spirit of the Malacca Cane," is said to affect this plant particularly. In fact, a sound has been wrongly attributed to an animal, the animal has been named accordingly, and finally an elaborate legend has grown up to explain the name. Explanatory myths of the kind may become even more elaborate, and may attempt to explain other matters besides names.

There is a little black and scarlet flower-pecker—*Dicæum nigrimentum*, I think—which is known as *Būrŏng Sĕpāh Pūtrī*, or "Princess's Quid of Betel Bird." No white man who had ever seen a Malay woman chewing betel could doubt the origin of the name—her blackened teeth and scarlet saliva; but the Malays have thought it necessary to invent the following myth. The Owl was in love with the Princess of the Moon, and asked her to marry him. Being too polite to give him a direct refusal, she spat out the betel which she was chewing, and said that she would be his, when he returned it to her. But the betel was immediately transformed into the *Būrŏng Sĕpāh Pūtrī*, which the Owl is for ever pursuing. This also explains why owls hoot at night—they are making love to the Princess of the Moon.

The stories already told (for several of which I am indebted to Mr W. W. Skeat's "Malay Magic") have this in common—that they are all theories constructed to explain zoological facts; although, like many other theories, they are built up upon foundations that are not always accurate, and although there are many persons—in their case the persons happen to be savages, or rather barbarians—who look upon

them as facts. The grain of truth to be found in each may be very slight indeed, or it may be considerable in extent but of obscure outline. Some zoological beliefs of the Malays, however, appear, from whatever standpoint they may be considered, whatever allowance for the lack of critical insight in their originators may be made, to be utterly opposed to common-sense.

In the case of several large pythons which I dissected in the Siamese Malay States, numbers of hard, bean-shaped bodies of a livid purple colour were scattered all over the body in the connective-tissue immediately under the skin. They were not parasites, but were evidently of a pathological nature; in a few instances open sores were formed directly over them. They were most numerous in a python of no great length—less than thirteen feet—which was infested to an almost incredible extent by animal parasites; its intestine was pierced by large nematodes in bunches, its alimentary canal contained numerous tape-worms, its lungs were infected by Linguatulids, and its skin, which tore like paper, with two different kinds of ticks. I have only made the most superficial microscopical examination of these structures; but possibly they are due to a form of tuberculosis, to which it is said that pythons are liable. The Malays whom I questioned about them called them *Gagak Ular*, the "Strength of the Snake," and said that they were centres from which the constricting power of the python radiated forth. Probably many pythons existed without them, for, just as there were weak men, so there were weak pythons; but no snake which lacked them could possibly be strong. They were not thought to be the seat of the reptile's life, as that is believed to rest in the gall-bladder, but merely to act as reserves of power. A Malay-speaking Siamese magician, however, who used to assist me in dissecting snakes—no Malay having been found hardy enough to run the risk of fever, which those who "play with snakes" are believed to incur—called the structures either *Gagak Ular*, or *Hibu Ular*. Now *hibu* is a word which originally meant "adult," but which has gained many secondary meanings, such as "parent," "maker" of a nest or other habitation, "primeval

hoard." He appeared to have some idea that the *Hibu Ular* were germs from whence the snake had sprung within its own body. In either case, it was curious to find that structures, which were obviously harmful to the animal in which they occurred, should be considered most beneficial to it.

The above are selected samples of the zoological beliefs held by the Malays of the mainland, and they are typical of their conceptions of life in the concrete. I have avoided entering into the higher regions of zoological mythology and folklore, as it would be impossible to treat them adequately without describing the religion and superstitions of the Malays at greater length than would be justifiable in the present paper.

Like all primitive languages, Malay is deficient in general terms, but rich in specific names. In zoological nomenclature, however, this is less noticeable than in some other branches of the language. The Malays have a general name for birds—*būrŏng;* for snakes—*ūlār,* which also includes cæcilians and certain worms; for tortoises—*kūrā-kūrā;* for frogs and toads—*bĕrkātāk;*[1] for fish—*ĭkăn;* for shelled molluscs, whether univalve or lamellibranch—*sīpūt;* for worms—*chăchĭng;* for spiders—*lābā-lābā;* for flies—*lălăt* (but mosquitoes are called *nyāmōk*); for ants—*sĕmūt;* for butterflies—*kūpū-kūpū,* which also includes dragon-flies; for fixed cœlenterates and sponges—*būngă kārăng* ("reef flowers"). The word *bĕlălăng,* derived from *lălăng,* the long grass in which many grasshoppers live, means primarily a grasshopper or locust, but is generally extended to all Orthoptera which are neither cockroaches (*līpăs*) nor earwigs (*sĭpĭt-sĭpĭt*)—from *sĭpĭt,* a pair of forceps. But in Malay, as in ordinary English, a mammal cannot be described more accurately than by calling it a "four-footed beast," *bĭnātăng āmpăt kāki;* there is no general name for lizards (*Mabūia* and the skinks generally being called *bĕnkārŏng;* small geckos and *Draco*,[2] *chīchāk; Varanus, Gecko stentor* (*Biawak Ponggok,* or "Owl Lizard"), and *Liolepis biawak* (*Biawak*

[1] Final *k* is mute in the dialects spoken in the Malay Peninsula.
[2] But *Draco* is also called *Bidadari*—the "celestial nymph."

Pasir, or "Sand Lizard"); *Calotes* and its allies, *sŭmpăh-sŭmpăh*): some beetles are classed as "grubs" (*ŭlăt*), some as *rĭăng-rĭăng*, and many have only specific names.

In all those animals which are recognised as belonging to a definite class, the name of that class is prefixed to their proper designations, if proper designations are recognised for them. But, in some classes, proper names are rare; thus I have only heard one among the spiders—*Lābā-lābā Lōtŏng*, or Monkey Spiders, the gigantic burrowing forms belonging to the Mygalidæ. (*Lōtŏng* is the Malay name for the Spectacled Monkey, *Semnopithecus obscurus*.) No distinctions are made between different butterflies, except that the larger species of the Papilionidæ, which have much black in their coloration, are known as *kupu-kupu lang*, or "hawk butterflies." All mammals and birds, however, the vast majority of fish, snakes, frogs, and tortoises, as well as those grasshoppers, ants, or Hemiptera that are at all conspicuous or peculiar—and some that are not conspicuous or peculiar also—have proper names.

It is possible to distinguish between the rudiments of a binominal, or rather trinominal, classification in Malay zoological terminology. As a simple case, we may take the name *ulat chălowa*, which is applied to Peripatus, to several slugs, and, according to some Malays, to land planarians. *Ulat chalowa ĭtăm*, the "Black *Chalowa* Grub," is a species of slug; *Ulat Chalowa Puteh*, the "White *Chalowa* Grub," is another; but *Ulat Chalowa Bĕrkāki*, the "*Chalowa* Grub with Feet," is Peripatus. The most complete instance of this kind of nomenclature that I know is that of the *Ular Kāpak*,[1] or "Axe Snakes"—an assemblage of small snakes, which, though they are not related in reality, yet exhibit a certain indefinable likeness to one another: the majority of them are distinguished by a white "collar," not unlike that of our own Ring Snake. If a collection of snakes was put before me, I would have no hesitation in picking out those which the Malays would class as "axe snakes." There is the

[1] For the identification of the different "Axe Snakes," see Mr F. F. Laidlaw's paper on the reptiles of the Skeat Expedition.

Ular Kapak Āpī, the "Fire Axe Snake," whose bite produces a burning sensation; the *Ular Kapak Ayĕr,* the "Water Axe Snake," which lives in marshes; the *Ular Kapak Daun,* or "Leaf Axe Snake," which is green, and lives in trees; the *Ular Kapak Mālăs,* or "Lazy Axe Snake," which is too sluggish to get out of the way when the log under which it sleeps during the day is overturned; the *Ular Kapak Līma Kĕnd'ri,* or "Five *Kend'ri* Axe Snake," so called because the effects of its bite can be cured for the sum of fifteen cents (five *kend'ri*); the *Ular Kapak 'Rīmau,* or "Tiger Axe Snake," whose body is conspicuously marked with bars; and there are many other axe snakes also, whose names I do not know. Some are harmless, and a few are venomous; but they are all small, the majority being quite minute.

Malay names of animals are often very local. Thus, the brilliant blue-and-coral snake *Doliophis bivirgatus* is known in the Patani States as *Ular Sīna Māta-Hāri,* the "Sunbeam Snake"; but in Kelantan it is called *Ular Tăngăn Bājū,* or "Coat-Sleeve Snake." In Ualor, *Belalang Gāmbōr* ("Image Grasshoppers") are the Hooded Grasshoppers which belong to the genus *Capnoptera,* and which exhibit a brilliantly-coloured bladder behind the head on being alarmed; but when I asked for *Belalang Gambor* in Kelantan, the natives invariably brought me specimens of the large locust *Acridium succingtum.*

Many Malay names of animals are derived from the sounds they give forth. Thus, the *Wa-wa* (*Hylobates lar*) is so called because it howls at sunset and sunrise like a person in torture. The term *riang-riang* is applied both to Cicadæ and to Melolonthid beetles, though it is obviously derived from the noise which the latter produce when they fly; as the stridulation of the Cicadæ does not at all resemble the name they share. Both Cicadæ and beetles—of which the commonest species is *Lepidota sigma*—stridulate in the evening, and commence to do so about the same hour; but I have noticed on several occasions that the nightly chorus of the insects is commenced by a single beetle, which buzzes about for several seconds alone. The noise which these

big cockchafers produce is also louder than that of most Cicadæ.

The *Bekatak Dĕmăm*, or "Fever Frog" (*Megalophrys longipes*), gets its name because its croak is supposed to resemble the groans of a Malayman very ill with fever. The Slow Loris (*Nycticebus tardigradus*), misnamed in the Straits the "Sloth," is called *Kŏnkăng*, because it is said to remain on one tree until it has eaten up all the leaves, and then to call out, "Konkang! Kongkang!" This causes the wind to rise, and to blow the branch of another tree within its reach. The *Burong Hūjăn-hūjăn*, or "Rain Bird," is the broadbill *Cymborhynchus macrorhynchus*, which screeches before rain.

Probably the greater number of Malay animals' names, however, refer to peculiarities of appearance or habit, and some of this class are most instructive. Two examples will suffice. The *Sūmpah-sūmpah* (the lizard *Calotes versicolor*) is called "Chameleon" by the Europeans in the Malay Peninsula, because of the power of changing its colour that it possesses; but its native name, derived from the word *sumpah*, "to curse," shows a deeper knowledge of the animal's habits than many white zoologists have gained. At the time of courtship the male *Calotes* posts himself in some conspicuous position, and goes through an elaborate dance before the female, who remains concealed. In this performance he solemnly raises his head, and as solemnly bows it again, all the while opening and shutting his mouth as if chattering rapidly, but without emitting the slightest sound. He appears to be cursing, and so the Malays have given the name of "Curser" not only to him, but also to several other allied lizards.

In the British official lists of poisonous snakes for which a reward is offered, the name *Ular Kĕtăm-Tĕbū* appears as that of the very venomous *Bungarus fasciatus*—a black and yellow snake, coloured in bands which appear to be conspicuous, but are probably protective in reality; but in the Siamese States, where *B. fasciatus* is rare, the name *Ular Katam-Tebu* is generally given to *Dipsadomorphus dendrophilus*, a large snake, which is probably harmless to man,

but is coloured in a similar manner, except that the yellow bands are comparatively narrow, and do not completely encircle the body. *D. dendrophilus* is nocturnal in its habits, and lives among long grass or mangrove roots. In such an environment it is concealed by its stripes, just as a tiger is concealed among reeds. Now *katam-tebu* are little round pieces of yellowish sugar-cane, pierced together on skewers of bamboo, and sold in the Malayan markets. In the snakes, the yellow bars are taken to represent these pieces of sugar-cane, and the black bands the spaces between them. Thus we see that the Malay name exactly expresses what does take place in nature, for the object of the coloration of these snakes appears to be that they may be concealed in an environment in which actual objects of a more or less yellow colour alternate with black spaces.

Of course it would not be safe to adduce much from mere names given to animals by unscientific people like the Malays, for their own surmises are often glaringly inaccurate. For example, they call the tadpoles of *Ichthyophis glutinosa*, *Ular Tĕdŏng Sĕndōk Rŭăm*, because they believe that these larvæ bite like the cobra (*Ular Tedong Sendok*, "Spoon-hood"), and turn into a fish called *Ikan Ruam*. I was once led into a singular error by speculating upon a Malay name. At Biserat, in Jalor, where there is a considerable Siamese population, the adult *Ichthyophis* is sometimes called *Ular Bĕlō Gĕlĕnggŏng*, sometimes grouped together with *Typhlops* and *Cylindrophis* under the descriptive terms *Ular Kăpālă Ĕkōr* ("Tail-headed Snake"), *Ular Dua Kapala* ("Two-headed Snake"), and *Ular Tanah* ("Earth Snake"), but very generally known as *Ular Klĭng*. Hearing the last name first, and being ignorant that the ordinary Siamese name for *Ichthyophis* is *Ngu Kling*, I concluded that the *Ular Kling* was so called because it was black like an *Orang Kling* or Tamil, and I entered a provisional note to that effect in my note-book, a Malay having politely agreed with me when I broached the theory in conversation. This was in the days of my inexperience, and I became distinctly wiser when I discovered that the name had simply been

adopted from the Siamese, probably without a thought as to its meaning.

It was with diffidence that I determined to bring the names and stories noted in this paper to the notice of the Royal Physical Society; but I have done so believing that, quite apart from any interest they may have in themselves, they may be useful to naturalists and collectors in foreign countries. My experience, slight as it has been, has taught me that it is usually possible to obtain from native collectors specimens of animals of which the nature, names, or legends can be given, and that many zoological facts may be gained by a careful and judicious study of native beast stories and zoological names.

XXXII. *A Suggestion on Extinction.* By C. B. CRAMPTON, M.B., C.M.

(Read 20th March 1901.)

I think we may consider it an established fact that once an animal or plant has undergone extinction, it never recurs. All the evidence from palæontology and stratigraphy points strongly to this being the truth. Many theories have been put forward to account for extinction. Most of these have taken into consideration the environment as the instrumental cause; either some change in the inorganic conditions, as, for example, differences in the climate or in the relative position of land and water, or else the relations which exist between the different individuals and groups of animals and plants in their mutual adjustment to their surroundings.

There can be no doubt that the above-mentioned causes have been sufficient to account for the *local* extinction of faunas and floras, and also that they have been the *immediate* causes of the final disappearance of forms that were already rare and on the road to extinction. These causes, indeed, are still in evidence as regards our present fauna and flora, where certain forms are ready to undergo extinction on very slight adverse changes in their surroundings.

On the other hand, the great amount of destruction that

can take place amongst living forms that are dominant, without leading to their extinction, is a matter of common observation. However, I think it is still a question for controversy whether these environmental causes are quite sufficient to account for the wholesale disappearance of large and prominent groups which had become dominant over wide areas of the earth's crust in past geological history. I refer to such groups as are shown on the diagram. Zoologists who have made special study of the geographical distribution of organisms, are tending towards the opinion that animals and plants are much more plastic to changes in their physical surroundings than was formerly thought. They have put forward evidence that barriers to migration are a most important element in the distribution of faunas and floras, both in the past and at the present. It is highly probable that much extinction has been brought about by the breaking down of such barriers to migration in the past with the mixing of two faunas and floras which were originally isolated from one another. This, however, if sudden, can only have acted locally, and any cases involving wide areas will have required geological time; and the whole is involved in the question as to the relation that extinction bears to the struggle for existence. The study of evolution and geological history teaches us that organisms can slowly change from a marine to a land or fresh-water habitat, or again from a littoral or land to an oceanic existence. These developments involve geological time, and more or less alteration in the anatomical structure of the organisms. The power of adaptation to new surroundings, through variation, in some of the lower forms of life, seems indeed almost unlimited. We are not entirely without evidence, moreover, that such changes do occur in some degree with wonderful rapidity amongst forms in the present fauna. Any suddenly-produced changes in the physical surroundings, however, can scarcely act more than locally, and, indeed, all ideas of sudden general extinction of forms of life in the past have been put aside as untenable, since they are not in accordance with the well-founded opinions in geology or in the evolution of organisms. To the slowly-produced physical changes, on

the other hand, which have acted over wide areas during geological history, the degree of plasticity of organisms seems quite capable of answering. The great degree of this plasticity to the surroundings, through variation, which occurs within the limits of closely-related groups, is demonstrated by the very wide variation in the habits and modes of existence of forms which have undoubtedly sprung from a near and common ancestor. Such considerations as the above, and many more which might be added, would suggest that the changes in the *physical* conditions of the past have not been the *sole* cause of the extinction of large groups of animals and plants which had become dominant and widespread.

The view regarding extinction, which considers the mutual relations which exist between the different individuals and groups of animals and plants to their environment, is the one which was so ably advocated by Darwin in his "Origin of Species," and therefore requires the closest consideration. He pointed out that the destruction of life which ensues from the struggle for existence, and consequent Natural Selection, would be sufficient to account for the constant extinction in the fauna and flora of the past. He, in fact, goes so far as to say that it would be folly to wonder at extinction when we consider the enormous destruction that must take place amongst the forms that were not successful in the struggle for existence. I need hardly say that the very large part which is taken by Natural Selection in survival and extinction throughout all forms of life is only too apparent, and its demonstration must be thoroughly satisfactory to all who believe in evolution. This would be the sole necessary explanation for the extinction of groups in the past, provided we were quite sure that there was not some factor coming from within the organism which tends in time to cause a weakness of the individual in relation to its environment or an increasing want of fertility. Should such be the case, the often-repeated suggestion of the likeness of the life-history of a group in time with its periods of onset, dominance, degeneration, and extinction, to the life and death of the individual, would be indeed more than a mere simile. The study of the ranges in time of the extinct groups in the

past, together with the degree of specialisation to which they attained, and also some well-known, though at present unexplained, facts in zoology and physiology, seem indeed to strongly suggest that there is a time of life for the species or group which is connected with the rapidity with which specialisation takes place. There is an increasing opinion that no form of life can undergo repeated fission, budding, or self-fertilisation for more than a certain number of generations, without bringing about its own extermination. The experiments of Maupas have proved this to be the case at any rate as regards the fission of some of the ciliate Protozoa, and in the higher forms of life there seems to be a necessity for a sexual generation sooner or later to occur to prevent a dying out of the stock. As we proceed from forms of less specialisation to forms of greater specialisation, this cross becomes apparently an increasing necessity, and gradually fission, budding, and all forms of asexual reproduction are lost, and at the same time the powers of architectural repetition and also of reproduction of lost parts becomes less and less evident. Amongst plants this loss of a generalised power is not so obvious, owing to the line of increasing anabolism along which they have specialised, but the increasing necessity for cross fertilisation is quite apparent.

A cross between individuals not of the same stock, in all cases brings about a greatly increased vitality, or what is usually termed rejuvenescence. In some cases resting-spores are produced, with great powers of resisting death from desiccation or other injuries. In other cases it is the starting-point of a very vigorous multiplication, and in all the higher forms of life, of the marvellously rapidly-produced growth and specialisation of embryonic existence. Amongst forms of high specialisation, the blending of individuals of near ancestry seems to have a very detrimental result, with very frequently a tendency to increasing sterility, as well as a general weakness of the individual in relation to its environment. This point, I believe, has been disputed by many zoologists, who hold that there are no ill-effects produced from continued in-breeding; but it is asserted by Darwin to be the general belief amongst breeders "that

close in-breeding diminishes vigour and fertility," and he himself made many experiments tending to corroborate this opinion. I have also found from other sources that this is a very general opinion amongst farmers and breeders of poultry and cattle. The constant attempt on the part of nature to ensure cross-fertilisation amongst fixed animals and plants is sufficiently convincing that there must be a deep-seated factor underlying in-breeding which tends to its elimination as far as is possible. The effect of close in-breeding in man himself appears to affect the very system in which he is most specialised. That this is the general opinion is evident from the laws of all civilised nations. Some medical men, however, are inclined to think that there is no bad result unless there is a neurotic tendency already present in the family. This would only lead one to ask what produced the neurotic tendency. It can only have occurred as a variation, and may not the same cause which produces the neurotic tendency be also the cause which produces the ill-effects due to too close in-breeding? I have myself, in several cases of families in which all or several of the children were deficient in some part of the nervous balance, found on inquiry that the parents were cousins. There is no doubt that in-breeding tends to aggravate to an unexpected degree any nervous tendency that may be present in the parents.

Turning to the palæontological side of the question, I will first give some of the inferences that may be drawn from it, and afterwards rapidly pass through some of the more striking cases that I have noticed as regards range in time and other points that would lead to such inferences in the different groups of animals in geological history.

In the first place, the lowly-organised groups have persisted in spite of the gradual evolution of more and more highly-organised forms, and that this must be due in large measure to their rapid growth and reproductive powers.

(2) That groups appear to have a shorter range in time as they acquire a higher degree of organisation.

(3) That living forms of groups that are dominant at the present time rarely show ancestors of such great specialisation as themselves.

(4) That forms that are now isolated in their zoological affinities, and bordering on extinction, are generally highly specialised in some direction, but often show some signs of degeneration, and usually have ancestors of greater specialisation during some former period of dominance. A few, at any rate, seem to show a smaller degree of fertility than might be expected.

(5) Other forms which have come down to us from a distant period with small amount of change, or with very gradually-acquired specialisation, often show a great resistance to death. They are also generally extremely fertile.

(6) That extinct groups seem almost invariably to have acquired a great degree of specialisation during their period of dominance.

(7) That the more specialised genera and species of groups tend to have a shorter range in time than the less specialised, although they frequently appear to have temporarily acquired a greater dominance.

(8) When a group shows very quickly-acquired variation and specialisation, its range is usually very restricted.

(9) That the later forms in extinct groups frequently show signs of degeneration, and sometimes a more primitive organisation than the most specialised forms, possibly owing their persistence to their slower specialisation.

(10) That long retention of primitive characteristics, or a great degree of stability and want of variation, has been usually associated with a long range in time.

And lastly, higher groups do not spring from the most specialised forms of the parent groups before them in time, but from some more generalised forms in those groups which had retained a more primitive organisation.

Lowly-organised forms generally show a long geological history, as might be expected. Radiolaria are known from the earliest deposits, and are found throughout the geological sequence in those rarely-occurring rocks which were laid down under suitable conditions for their preservation. About two-thirds of the two thousand species of Foraminifera that have been described occur in the fossil state, and, according to specialists, the longevity of certain genera, and even

species, is very remarkable. *Lagena, Nodosaria,* and *Textularia* are in each case simple forms in the groups in which they occur, and with great uniformity of architecture. The two former range from the Silurian, and the latter from the Carboniferous to the present day. On the other hand, we find very specialised forms often of large size, such as *Fusulina* and *Schwagerina,* with a world-wide distribution, during the Carboniferous, where they occur in such myriads as to form great beds of limestone. They are, however, entirely confined to that system. The development of enormous species of Nummulina in the early Tertiaries, with a complicated canal system, took place with remarkable rapidity, and over a wide area. This development, again, however, was exceedingly short lived. The Graptolites, which had a world-wide distribution in early Palæozoic times, must have existed in enormous profusion, and underwent a degree of variation which is very extraordinary considering the simplicity of their type of architecture. They, however, suddenly disappeared at the end of Silurian times.

The genus *Dictyonema,* which, if a Graptolite at all, has a very generalised organisation, ranges from the Cambrian to the Devonian. The two genera, *Diplograptus* and *Climacograptus,* which appear to be the more generalised genera of the true Graptolites, occur throughout the Ordovician and Silurian rocks, a peculiarly long range compared with other genera, which appear to be more specialised, and have much more restricted ranges.

The Lithistid and Hexactinellid sponges have existed since early Cambrian times. The Calcispongiæ, however, are not found till late in the Palæozoic, and only became of any importance in the Mesozoic period. Of these latter, the *Pharetrones,* which have the largest and most complex organisation, underwent complete extinction, following their greatest development in the Cretaceous. The great variety in the vegetative architecture in the genera of fossil sponges is only as remarkable as the very short range in time shown by the more extraordinary forms throughout geological history. It might be suggested that the possibilities of cross-fertilisation amongst forms like the sponges, which depend

on a system of budding to form fixed colonies with periodic liberation of sexual cells, would appear to be a more precarious condition than in those creatures, as, for example, the Hydroids, which have migratory sexual persons, or even in plants, which, although fixed, have such complex contrivances to secure it through the agency of insects or otherwise.

As regards the corals, the Rugose and Tabulate divisions are almost entirely confined to the Palæozoic. They showed great variety in form in the number of genera and species before undergoing extinction. The Hexacoralla are first found in the Trias, and have continued to the present day. The genera of corals on the whole show remarkably short range in time considering the low degree of organisation to which they attain. The longest ranges are found in *Zaphrentis*, *Petraia*, *Clisiophyllum*, and *Strephodes* amongst the simple Rugose corals, with a range of Silurian to Carboniferous, and the same range is found in the compound forms *Cyathophyllum* and *Dyphyphyllum*. Amongst the Hexacoralla four genera only range from the Jurassic to the present day. *Favosites* and *Syringopora*, of the Tabulate division of the Rugosa, range from Silurian to Carboniferous. The extinct Echinoderm groups of Cystoids and Blastoids did not survive the Palæozoic. The great variety of form in both groups, considering the number of species that are described, is very remarkable. About 50 genera of Cystoids have been made for the 250 species that are known; and 19 genera, with about 120 species, are recognised by Etheridge and Carpenter for the Blastoids. The genera and species of both Cystoids and Blastoids show very short range in time.

The Crinoids have apparently been declining ever since their maximum development in the early Palæozoic. The groups that existed during that time of dominance are characteristically highly specialised and of perplexing variety, and the range in time of the different forms is very limited. There is one family, however, which has a peculiarly long range of existence. This family is the Ichthyocrinidæ, which range from the Ordovician to the top of the Carboniferous. The two genera *Ichthyocrinus* and

Taxocrinus, indeed, have almost the same range. This group appears to have some very generalised characters in comparison with its Palæozoic relations, and seems, moreover, to be in some measure related to the later groups of Crinoids which came into existence in the Mesozoic, and have persisted to the present time. Amongst these later forms *Pentacrinus*, *Extracrinus*, and *Antedon* have persisted since the beginning of the Mesozoic with very little change.

Of the Echinoids, typically regular forms like *Cidaris* have existed ever since the Trias. The suddenly produced large numbers of irregular forms, like *Echinocorys* in the Cretaceous, was followed by a very quick extinction of many of the genera, though both regular and irregular forms have continued in abundance to the present time.

Fossil Polyzoa are found plentifully throughout all the deposits as far back as the Ordovician. Some of the simpler genera of the Cyclostomata, as *Stomatopora* and *Berinicea*, have ranged throughout the whole of that time, and a great many living genera of the same division range far back into the Mesozoic. The peculiar group of Monticuliporoids, which some consider as related to the Polyzoa, and which acquired such dominance in Ordovician and Silurian times, and underwent such variety in form and structure, doubtfully survived the Palæozoic. The same range is found in the specialised group of the Cryptostomata which contains the bulk of the Palæozoic Polyzoa like *Fenestella*, *Polypora*, *Rhabdomeson*, and their allies. The Chilostomata, which form the bulk of living Polyzoa, only date back to the Jurassic.

The Brachiopoda, like the Crinoids, showed their maximum development in Palæozoic times. The great abundance and extraordinary specialisation of forms of *Productus*, *Spirifer*, *Pentamerus*, *Cyrtia*, *Merista*, *Uncites*, and *Stringocephalus*, as well as their variety in shape and size and in the condition of their brachial supports, is quite in accordance with the comparatively short range of these genera, and especially of the more remarkable species. The long-winged forms of *Spirifer* became extremely dominant in the Devonian, but underwent as rapid an extinction. The simple *Spirifer*

glabra, on the other hand, persisted from the Devonian on into the Carboniferous. Indeed, throughout the Brachiopoda any sudden development of some extraordinary character or large growth in size seems to have been followed by as speedy an extinction. In the Mesozoic there is a great falling off in the number of genera and species, and the forms are chiefly restricted to the persistent *Terebratula* and *Rhynchonella* types. Amongst these there is much slight variation in the external markings, accompanied by great persistence of type, but we also get outstanding specialised forms in *Lyra, Magas, Kingena,* and *Trigonosemus,* and these are strictly Cretaceous, whilst *Pygope* and *Dictyothyris,* other specialised branches of the *Terebratula* stock, have limited ranges in the Jurassic. Throughout the whole of the time from the Lower Palæozoic onwards, the *Lingula, Crania,* and *Discina* types have persisted and are still existing.

These three types of the Inarticulate division of the Brachiopoda have shown very small range in variation throughout, and their appearance has been very stable, but never in great abundance. They may be truly termed persistent types. It is in this division of the Brachiopoda that hermaphroditism occurs, so rare a condition in the class. It is noteworthy that the existing *Lingula* shows great resistance to death, and seems to have the power of surviving after being out of water and in a dry condition for some time.

Turning to the Lamellibranchs, we find very persistent types with exceedingly small amount of variation in *Solenomya,* which has persisted since Carboniferous times with very little change, and *Nucula,* which ranges from the Silurian onwards. Curiously enough, both these forms are classified by zoologists in the primitive group Protobranchia, with exceedingly simple gills and a sole for creeping on the foot. As a contrast to these, and showing great specialisation, and often to an extraordinary degree, and all with limited range in time, we may compare the forms grouped together as Rudistæ. Such are *Diceras* from the Upper Jurassic, and *Requienia, Monopleura, Caprina, Spherulites,* and *Hippurites,* and several other less known forms from the Cretaceous. These extraordinary molluscs had a world-wide

distribution, and often occur in such numbers that whole beds of limestone are almost entirely built up out of their shells. Their onset was very sudden, and their extinction apparently as rapid. The allied form *Chama*, which has remained since the Cretaceous, appears to owe its persistence to not having taken part in this wonderful specialisation.

Passing on to the Scaphopoda, we find the curious *Dentalium*, ranging from the Ordovician to the present day. There are many species, but the type is very strictly adhered to, and the variation very slight. Its appearance is very constant, but rarely in great numbers.

The Chitons have undergone a very slowly increasing specialisation from the Ordovician onwards. They are never common in the fossil state, only about seventy species having been described from all known horizons, and the group appears to be more dominant at the present time than at any former period of geological history. Their very generalised position amongst the Mollusca accords well with this slowly acquired specialisation and persistence of type.

The Pteropoda are only known with certainty to date back to the Cretaceous. To these the curious genera *Tentaculites*, *Hyolithes*, *Conularia*, and their allies are very doubtfully related. *Tentaculites* occurs in extraordinary profusion in the Silurian and Devonian rocks, and then became extinct. *Hyolithes* ranges from the Cambrian to the Permian, and *Conularia* from the Ordovician to the Lias, both with great persistence of type.

Amongst the Gastropoda, patella-like forms have existed since the early Palæozoic. *Capulus* and its allies appear to have had greater dominance in early Palæozoic times than at any other period of their existence. The genus *Capulus* itself has persisted from the Cambrian to the present day. Various genera belonging to the family are stationary throughout the greater part of their existence attached to some foreign body, and sometimes overgrown by it. It is a curious coincidence of sluggishness of habit, accompanied by long duration in time. The genus *Pleurotomaria* also has a range from the Cambrian to the present time. It is very rare during the Tertiary, and the five living

species are exceedingly uncommon, and mostly of large size. During the Palæozoic and Mesozoic it abounds in the deposits, and its ornamentation is very various. It appears, therefore, to differ in these respects from most other types showing great persistence in time. On the other hand, the genera and species of the family Nerineidæ, with their extraordinary specialisation of the columella, have very short ranges, and the whole group is entirely Mesozoic.

The Nautiloid type has shown great persistence ever since early Cambrian times, and with very little variation in the character of the shell. It contrasts well with the extraordinary variety of forms developed, as specialised branches of the Nautiloid stock during its period of dominance in the Palæozoic. Even amongst these the simple genus *Orthoceras* has the longest range, extending from the Cambrian to the Trias; and the members of the family Orthoceratidæ, as a whole, have long ranges in comparison with the more specialised groups. The extraordinary variety of specialisation attained to in the Ammonites is as remarkable as the exceedingly limited range of time shown by the different genera and species, and the enormous numbers in which they must have existed. There is a peculiar tendency in many of the groups of fossil Cephalopoda to show, during their decline preceding extinction, forms which may be compared to senile or gerontic forms of less specialised species and genera. The Ammonites apparently underwent complete extinction on the close of the Mesozoic period, unless we have in the Octopoda that are now existing forms sprung from the same stock, with complete loss of the shell.

The Belemnites range from the Trias to the Cretaceous. *Aulacoceras* of the Trias has a very large phragmacone, somewhat resembling *Orthoceras,* and the guard is proportionately small. The typical Belemnites of the Jurassic have a large dactyliform guard, with the phragmacone greatly reduced. During this development they appear to be at their maximum, and abound in the deposits. Whether the *Spirulirostra* of the Tertiaries, and *Spirula* which is still existing, are forms which have persisted owing to not having taken part in such a specialisation of the guard, it would be interesting to know.

Turning to the Crustacea, we find forms belonging to the Branchiopoda ranging with great persistence, and with very small amount of change. *Estheria* is found from the Devonian onwards, and *Apus* dates back with little variation to the Trias. The Branchiopoda, as a group, have great powers of resistance to their surroundings, and the ova exceptionally so. The small amount of variation might be put down to the habit of prolonged periods of parthenogenesis, so frequent in the order; but, on the other hand, it seems that the great stability of character in the group may denote great powers of clinging to an unspecialised condition, in which cross-fertilisation would only be required at long intervals, to prevent the ill effects produced by long-continued reproduction of an asexual type.

Ostracoda abound in all the deposits from the Lower Palæozoic onwards. The genera and species tend to have very long ranges in time. *Bairdia*, *Cytherella*, and *Cypridina* occur from the Ordovician to the present day with very small amount of variation. The *Cirripedia* show a slowly-increasing specialisation from the Lower Palæozoic onwards, and are never abundant as fossils.

The genus *Nebalia* and its allies are the few remaining forms of a group that attained much greater specialisation during Palæozoic times. The many very peculiar and specialised genera, which occur in the deposits from the Cambrian to the Carboniferous, have a very wide distribution in space and extremely limited range in time. *Nebalia* has been shown to have the power of living in water which is sufficiently poisonous to destroy most organisms.

The few fossil forms of the Schizopoda which occur in the Palæozoic rocks are strikingly like their living representatives, some of them, perhaps, with even more specialised characteristics. They appear to have been a very persistent group, with slowly-acquired specialisation.

The Decapoda first appear in the Trias, and become increasingly important, and acquire their greatest specialisation and dominance at the present time.

The Trilobites appear in the lowest Cambrian in an advanced condition of specialisation, and quickly acquired their maxi-

mum of numbers of genera and species in the Ordovician, after which they slowly declined till their complete extinction in the Permian. The accompanying Chart, based upon Zittel, shows the ranges of the different families, with the number of genera and subgenera. It is to be noticed that a small number of genera in a family tends to be associated with a long range in time, and that these genera, on the whole, show longer ranges than those of the more variable families. A list of British Trilobites, with the longest ranges, shows that they also fall within these families.

Limulus, the living representative of the Merostomata, is found in the fossil state as far back as the Trias. These fossils show that it has undergone very little change, and the forms now living in widely separate seas are very similar. It would appear, therefore, to be a very stable type. *Limulus* is another of those forms which show a great resistance to death.

Of the Palæozoic Eurypterids, by far the longest range is attained in *Eurypterus*, Silurian to Permian. The gigantic *Pterygotus*, which seems a more specialised genus, is only found in the uppermost Silurian and Old Red Sandstone.

The Scorpions, which appear to be related forms, existed along with these gigantic Merostomata, and range from the Silurian to the present day with remarkably little change.

It is, however, in the study of the extinct Vertebrata that it seems we are likely to arrive at any conclusion as to the results of rapid specialisation. Unfortunately, my knowledge is necessarily very limited, and I will only attempt to point out a few of the most general points bearing on the question.

Amongst the fishes, it is easily observed that the extinct groups, like the Ostracodermi and the Arthrodira, attained a very high degree of specialisation in their own direction before they became extinct. On the other hand, the Elasmobranchs, which have had such an extraordinary persistence, appear to have retained in large measure a very primitive degree of organisation, although so specialised in other directions, and having acquired a method of reproduction allied to the higher vertebrates.

Whether the existing Dipnoi and Crossopterygian fishes,

now so isolated in the modern fauna, owe their persistence to any retention of more primitive characters than their extinct relations, would be an interesting inquiry. The degree of specialisation and size acquired by the Labyrinthodonts before their extinction in the Trias is only too apparent.

Amongst the groups of Reptiles that were so dominant during the Mesozoic we have two persisting, widely distributed, in the *Crocodilia* and the *Chelonia*, and one, the *Rhynchocephalia*, almost on the point of extinction. Of the *Chelonia*, Dr A. S. Woodward remarks that "the earliest known remains of the shell from the Upper Trias appear to be as typical as the corresponding parts of a modern tortoise, and the remains of skulls and limbs in the Upper Jurassic are so similar to those of living forms, that they scarcely unite the three suborders as now differentiated in the modern fauna." It is evident, therefore, that this group varies with extreme slowness, and one cannot help uniting with this its persistence in time as well as the sluggishness of the physiological functions and great powers of retention of life exhibited by the order. The great fertility of some of the members of the group is also very remarkable—some turtles are said to lay two hundred and forty eggs or more within a short space of time.

The *Crocodilia* have shown increasing specialisation since the early Mesozoic. Their limbs have throughout retained a very generalised condition, and the peculiar specialisation of the fauces, with the position of the eyes and nostrils, was acquired through a long series of forms, and only showed its present degree of perfection in Tertiary times. The crocodiles also are extremely fertile, laying as many as one hundred eggs or more.

The genus *Sphenodon*, of New Zealand, now so nearly on the verge of extinction, is the sole living representative of a group of reptiles which at so early period as the Trias showed a wide distribution in space, and frequently attained large size, with most extraordinary forms of specialisation. Other forms occur through the Mesozoic and also in the early Tertiaries, where *Champosaurus* appears to have had an aquatic existence. Singularly enough, according to Lyddeker,

this living relic is the least specialised form of the whole group, and perhaps may owe its persistence to this cause.

The intensity of specialisation attained to by those groups of Mesozoic reptiles that underwent extinction will be only too familiar to all palæontologists. The Ichthyosaurs, Plesiosaurs, Dinosaurs, and Pterosaurs seem literally to have taken possession of the land, air, and water, and underwent a marvellous degree of specialisation along many separate lines. The same remark applies to the Anomodonts, which, although so generalised in their affinities, were really forms highly specialised for several entirely different methods of life, as is seen in the Pariasaurs, the Theriodonts, and the Dicynodonts.

The extinct *Pythonomorpha*, which had a world-wide distribution in the Cretaceous, and did not survive that period, represent, according to Dr Woodward, an early stage in the evolution of the Squamata. Early forms of the latter, however, appear to have already been coexistent with these mighty reptiles, and one would rather look on them as a highly specialised branch of the early squamate stock.

If close in-breeding amongst living forms tends to produce sterility and also a weakness in relation to the surroundings, it is possible that the same cause which is at the bottom of the ill effects brought about by in-breeding is also the cause which produces the weakness which appears to be the result of long-continued specialisation within narrow limits.

In the first place, then, what is this cause, and the only answer is that we don't know. It is evident that if we wish to get further developments along a certain line of specialisation, the method is to breed true, or to pick out forms to breed from that do not deviate from the type of specialisation. It is also evident that what is termed true breeding has effects in horses and dogs and men that gradually merge into those that are the result of in-breeding. In the breeding of cattle and sheep, the very constant choice of rams and bulls of high reproductive power would tend at least to prevent the occurrence of sterility.

Now we suppose that all life has originally sprung through a one-celled condition, or something which we might com-

pare to a protozoan stage. The method of evolution along different lines has been very aptly compared by Darwin to the branches of a tree, and I agree with those who think there is good evidence that, once a form takes to one branch, it is limited in its path of evolution to that branch and its smaller branches, and once it takes to one of the smaller branches, it is limited to that branch and its buds to come. There is apparently no anastomosing of the branches, and no evolution from different stocks, converging to produce the same result.

To return to the one-celled primitive condition which lies at the roots of the tree, we see that it must have had a dormant power of variation, which, played on by natural selection, has produced such different results as a plant, a cœlenterate, an insect, a mollusc, a vertebrate, and so forth.

On the other hand, an insect has no powers of evolving a vertebrate as we understand them, nor a plant a mollusc. They seem, therefore, in comparison with the primitive one-celled condition, to have lost some of the possibilities of variation. Let us say, therefore, that they have less potential variation than the original one-celled condition. There would then be a certain potential variation for every group and every individual.

This potential variation, also, would become more and more limited within certain bounds at each stage in the evolution of the different forms of life, from which there is apparently only one method of return, and that with varying possibilities.

Even in the fauna, as it is at present constituted, there appears to be greater possibilities of wide variation in different directions in the lower forms of life than in the higher, although the Protozoa even must have specialised to a great extent since their original condition at the time they were evolved. On the other hand, the actual variation within the limits of possibility is apparently much more rapid in the highly organised forms of life, and, indeed, the more specialised they become, the more rapidly do they vary.

The evidence of the higher groups of creatures always having sprung from the more generalised forms in their

ancestral group, and not from the more highly specialised, would ensue from these generalised forms having retained a greater degree of this potential variation. It would therefore appear that the rate of actual variation is inverse to the degree of potential variation.

To go further, it is evident that in order to get continued variation in one direction, true breeding must be adhered to. This, indeed, would appear to be the reason of the tendency of domestic productions to continue varying so rapidly in one direction, namely, the extent to which selection is brought into play. At each step of this process, however, where a variation became fixed, it would seem that some potential variation in other directions is lost. It then only continues to vary within the limits mapped out by the potential variation that remains to it.

If we now turn to study what would be the effects of amphymyxis on this process, we note in the first place that as the specialisation advanced along a certain line, and continually lost potential variation, all the individuals of the stock would share in this change, though in different degrees. The consequence of this would be that the possible combinations and permutations of variation that could be produced through amphymyxis would be reduced within narrower and narrower limits at each step of the process. In fact, the range of unlike possibilities of variation in the two uniting cells would become more and more limited.

If we again look at amphymyxis in another light, namely, as to what is its apparent use in Nature, we notice that it is inevitable in most forms sooner or later to prevent extermination of the stock, and that the result is what may be termed rejuvenescence, and that it is usually followed by a great and rapid development. It seems to me, therefore, that there is a return of potential variation brought about by this union, or rather a check on the too rapid loss of this potential variation. If this be the case, the more specialised the stock becomes, the more limited would be this gain of potential variation, and the greater would be the rapidity of the actual variation. Also, within the limits of the stock, the more nearly related the individuals con-

cerned in the amphymyxis, or the more rigid the selection of forms that varied in the same direction, the greater would be the limit set on the resulting potential variation, and the more rapid would be the resulting actual variation. I may say that this result is apparently what does occur, not only as we proceed from lower to higher forms of life, but also as the result of true breeding by careful selection of variations of the type. It is also seen that if in-breeding on a close scale should occur, the potential variation that is brought about by the union may be so lessened that it becomes almost a matter of self-fertilisation, with possibilities of pathological results.

Let us next turn to see what effect Natural Selection would have in regard to these matters. It has been fully demonstrated by Darwin that specialisation is the result of Natural Selection. He pointed out that species are formed from species by a selection of certain variations of the parent species, and that by a process of what might be termed true breeding of these variations, and usually to the detriment of less successful types, in time such a divergence took place between the different selected variations that they ceased to congregate with each other, and often to be even fertile the one with the other, and that in this way new species came into existence. These new species would have their period of dominance, and produce new variations, upon which in turn Natural Selection would come into play, and again choose a few forms to start a new stock. In those forms which varied rapidly, Natural Selection would be most rigid, while in forms like *Lingula* and *Nautilus*, which tended to vary but little, the hand of death would be much more indiscriminate.

If we apply what has been said before regarding potential variation, we see that as Natural Selection is more rigid, the greater is the limit set upon the potential variation, and, moreover, that the individuals of the groups, however numerous they may have become during their period of dominance, are becoming more and more alike as regards the restriction of their potential variation. Natural Selection of a rigid kind would therefore tend to

cause a more rapidly-produced actual variation, and *vice versa* the increasing actual variation would give greater scope for the Natural Selection to act on. The one would play into the hands of the other. In course of time this process would bring about a condition of things where the individuals of a stock that was highly specialised along its own line would become so alike in their potential variation that the same cause of impaired fertility, and a weakness to the environment that is so evident as the result of close in-breeding, might come into play, with resulting extinction of the group.

JOURNAL OF PROCEEDINGS.

SESSION CXXVII.

Wednesday, 17th November 1897.—Professor J. STRUTHERS, M.D., LL.D., President, in the Chair.

The retiring President delivered an Opening Address "On Rudimentary Structures and their Meaning, in Man and in certain Animals."

Wednesday, 15th December 1897.—Professor J. STRUTHERS, M.D., LL.D., President, in the Chair.

The following gentleman was elected an Ordinary Fellow of the Society: Campbell Brown, Esq., M.A.

The following Office-Bearers for the Session were elected:

President—B. N. PEACH, F.R.S., F.G.S.

Vice-Presidents—ANDREW WILSON, L.D.S.; Lieut.-Col. BAILEY, F.R.G.S., F.R.S.E.; ROBERT MUNRO, M.A., M.D., F.R.S.E.

Secretary—R. H. TRAQUAIR, M.D., LL.D., F.R.S.

Assistant-Secretary—PERCY H. GRIMSHAW, F.E.S.

Treasurer—GEORGE LISLE, F.F.A., C.A.

Librarian—J. ARTHUR THOMSON, M.A., F.R.S.E.

Councillors — William C. Crawford, F.R.S.E.; Robert Kidston, F.G.S., F.R.S.E.; Lionel W. Hinxman, B.A.; Thos. Scott, F.L.S.; J. G. Goodchild, F.G.S.; R. Stewart MacDougall, B.Sc.; Professor Malcolm Laurie, M.A., D.Sc.; Professor J. Struthers, M.D., LL.D.; Professor J. Cossar Ewart, F.R.S.; J. S. Flett, M.B., B.Sc.; Lieut.-Col. R. G. Wardlaw Ramsay; T. B. Sprague, LL.D.

The Secretary, Treasurer, and Librarian submitted their Annual Reports.

The following communications were read:

1. "On the Nests, Eggs, and Playhouses of the Bower-Birds" (*Ptilonorhynchinæ*). By ARCHIBALD J. CAMPBELL, Esq., Melbourne. Communicated by J. J. DALGLEISH, Esq.
2. "Note on the Life-History of *Lochmæa suturalis*, a Beetle destructive to Heather, with Exhibition of Specimens." By PERCY H. GRIMSHAW, Esq., F.E.S.

3. "Obituary Notice of the late Professor HEDDLE." By J. G. GOODCHILD, Esq., F.G.S., F.Z.S.

4. Dr TRAQUAIR exhibited a Specimen of the Thicknee, *Œdicnemus scolopax*, shot at Muirhouse on 12th August.

Wednesday, 19th January 1898.—BENJ. N. PEACH, Esq., F.R.S., F.G.S, President, in the Chair.

The following gentleman was elected an Ordinary Fellow of the Society, James Davidson, Esq., Indian Civil Service (retired).

The following communications were read:

1. "On the Summer Birds of the Summer Islands.' By J. B. DOBBIE, Esq., F.Z.S., F.R.S.E., M.B.O.U.

2. "Results of Meteorological Observations taken in Edinburgh during 1897." By R. C. MOSSMAN, Esq., F.R.Met.S., F.R.S.E.

3. "Preliminary Note on an apparently new form of Trilobite from the Milburn Rocks of Westmoreland." By J. G. GOODCHILD, Esq., F.G.S., F.Z.S., M.B.O.U.

4. "Exhibition of abnormal Crustacean Appendages." By J. ARTHUR THOMSON, Esq., M.A., and the SECRETARY.

Wednesday, 16th February 1898.—BENJ. N. PEACH, Esq., F.R.S., F.G.S., President, in the Chair.

The following gentlemen were elected Ordinary Fellows of the Society: Alex. Morton, Esq., B.A.; Oswin A. J. Lee, Esq.; J. M'Lauchlan Young, Esq., F.R.C.V.S.; Harry Frank Tagg, Esq.

The following communications were read:

1. "On a Carboniferous Myriapod from East Kilbride." By the PRESIDENT.

2. "On the Occurrence in Spain of *Lycæna theophrastus*, Fab., a Butterfly new to the European Fauna, with Exhibition of Specimens." By PERCY H. GRIMSHAW, Esq., F.E.S.

3. "Concluding Notes on the Fossil Fishes of the Upper Old Red Sandstone of the Moray Firth Area." By R. H. TRAQUAIR, Esq., M.D., LL.D., F.R.S.

4. "Exhibition of a Specimen of the Three-bearded Rockling (*Motella tricirrata*, Bloch) from the Firth of Forth." By J. ARTHUR THOMSON, Esq., M.A, F.R.S.E.

5. "Exhibition of Injury caused by the Leaf-Cutter Bee (*Megachile centunculario*) upon Hornbeam and Rose." By R. STEWART MACDOUGALL, Esq., M.A., B.Sc.

Wednesday, 16th March 1898.—BENJ. N. PEACH, Esq., F.R.S., F.G.S., President, in the Chair.

The following gentlemen were elected Ordinary Fellows of the Society: Wm. Gunn, Esq., F.G.S., H.M. Geological Survey; Kenneth J. Morton, F.E.S.; Chas. W. Peach, Esq., M.B., C.M.

The following communications were read:

1. "On the Influence of Muscular Attachments in producing Modifications of the Popliteal Surface of the Femur, and Alterations in the Diameters of the Shaft of that Bone in the Popliteal Region." By DAVID HEPBURN, Esq., M.D.

2. "The Mammals and Birds of Franz Josef Land, with Exhibition of Specimens, and Lantern Illustrations." By WM. S. BRUCE, Esq., of the Jackson-Harmsworth Expedition, and WM. EAGLE CLARK, Esq., F.L.S.

3. "Exhibition of Specimen of Flexible Sandstone, and of the Nest of a Weaver Bird, from India." By ROBERT MUNRO, Esq., M.A., M.D., F.R.S.E.

Wednesday, 20th April 1898.—BENJ. N. PEACH, Esq., F.R.S., F.G.S., President, in the Chair.

The following gentlemen were elected Ordinary Fellows of the Society: Charles Porter, Esq., M.B., C.M.; John Crawford, Esq., M.B., C.M.

The following communications were read:

1. "On some new Silurian, Devonian, and Carboniferous Myriapods." By the PRESIDENT.

2. "A List of *Collembola* and *Thysanura* collected in the Edinburgh District." By GEORGE H. CARPENTER, Esq., B.Sc., and WILLIAM EVANS, Esq., F.R.S.E.

3. "On the Validity of *Pissodes validirostris* as a Species." By R. STEWART MACDOUGALL, Esq., M.A., D.Sc.

4. "On the Maintenance of the Earth's Internal Heat." By J. G. GOODCHILD, Esq., F.G.S., M.B.O.U.

5. "Solar Energy and Ice, with Lantern Illustrations." By J. G. GOODCHILD, Esq., F.G.S., M.B.O.U.

6. "On a Rock allied to Limburgite at North Berwick, with Lantern Illustrations." By J. G. GOODCHILD, Esq., F.G.S., M.B.O.U.

7. "Exhibition of Specimens of Crustacea from the Australian Coast, near Sydney." By J. STUART THOMSON, Esq.

8. "Exhibition of Specimens of a Phalangid (*Oligolophus Hansenii*, Kræpelin) new to the British list." By WM. EVANS, Esq., F.R.S.E.

SESSION CXXVIII.

Wednesday, 16th November 1898.—BENJ. N. PEACH, Esq., F.R.S., F.G.S. President, in the Chair.

The following gentlemen were elected Ordinary Fellows of the Society: Hugh Miller, Esq., F.Z.S.; Thomas Nicol Johnston, M.B., C.M.

The following communications were read:

1. "Contributions to the Natural History of the Polar Bear" (*Ursus maritimus*, Linn.). By REGINALD KŒTTLITZ, Esq., M.R.C.S., F.R.C.P. Communicated by W. S. BRUCE, Esq.
2. "Note on *Bryobia pretiosa* as a House Pest." By J. ARTHUR THOMSON, Esq., M.A., F.R.S.E., and R. STEWART MACDOUGALL, Esq., D.Sc.

Wednesday, 21st December 1898.—BENJ. N. PEACH, Esq., F.R.S., F.G.S., President, in the Chair.

The following gentlemen were elected Ordinary Fellows of the Society: David Waterston, Esq., M.A., M.B., C.M., F.R.C.S.E.; David Russell, jun., Esq.; James Bisset, Esq., M.A., F.L.S., F.G.S.

The following Office-Bearers for the Session were elected:

President—B. N. PEACH, F.R.S., F.G.S.

Vice-Presidents—Lieut.-Col. BAILEY, F.R.G.S., F.R.S.E.; ROBERT MUNRO, M.A., M.D., F.R.S.E.; J. S. FLETT, M.B., B.Sc.

Secretary—R. H. TRAQUAIR, M.D., LL.D., F.R.S.

Assistant-Secretary—PERCY H. GRIMSHAW, F.E.S.

Treasurer—GEORGE LISLE, F.F.A., C.A.

Librarian—J. STUART THOMSON.

Councillors—J. G. Goodchild, F.G.S.; R. Stewart MacDougall, M.A., D.Sc.; Professor Malcolm Laurie, M.A., D.Sc.; Professor Sir John Struthers, M.D., LL.D.; Professor J. Cossar Ewart, F.R.S.; Lieut.-Col. R. G. Wardlaw Ramsay; T. B. Sprague, LL.D.; Andrew Wilson, L.D.S.; J. Arthur Thomson, M.A., F.R.S.E.; William Evans, F.R.S.E.; Gregg Wilson, M.A., D.Sc.; William S. Bruce.

The Secretary, Treasurer, and Librarian submitted their Annual Reports.

The following communications were read:

1. "Results of Feeding *Drosera* with various Chemical Foods." By Miss HUIE. Communicated by W. C. CRAWFORD, Esq., F.R.S.E. With Limelight Illustrations.
2. "On the Age of the Shetland Old Red Sandstone." By J. S. FLETT, Esq., M.B., B.Sc.

3. "Exhibition, with Remarks, of Eggs and Embryos of *Platypus*, *Echidna*, and *Ceratodus*." By GREGG WILSON, Esq., M.A., D.Sc.

4. "Exhibition of Specimens of Eggs of *Xanthophilus bojeri* (Finsch and Hartl.) from Witu, British East Africa." By J. B. DOBBIE, Esq., F.Z.S.

Wednesday, 18th January 1899.—BENJ. N. PEACH, Esq., F.R.S., F.G.S., President, in the Chair.

The following communications were read:

1. "On the Genesis of some Scottish Minerals." Part I. By J. G. GOODCHILD, Esq., F.G.S.

2. "On the 'Rectal' Gland of the Skate." By JOHN CRAWFORD, Esq., M.B., C.M.

3. "Supplementary List (No. 2) of Edinburgh Spiders and some other Arachnids." By G. H. CARPENTER, Esq., B.Sc., and WILLIAM EVANS, Esq., F.R.S.E.

4. "Exhibition of Telegraph Instrument wrecked by Lightning at the Summit of Ben Nevis." By W. S. BRUCE, Esq.

Wednesday, 15th February 1899.—BENJ. N. PEACH, Esq., F.R.S., F.G.S., President, in the Chair.

The following gentlemen were elected Ordinary Fellows of the Society: Robert Turnbull, Esq., B.Sc.; Wm. Peach Hay, Esq., M.B., C.M.

The following communications were read:

1. "A List of the Collembola and Thysanura of the Edinburgh District." By G. H. CARPENTER, Esq., B.Sc., F.E.S., and WM. EVANS, Esq., F.R.S.E.

2. "On the recent occurrence in Scotland of Macqueen's Bustard (*Houbara Macqueenii*, Gray and Hard.); with Exhibition of Specimen." By W. EAGLE CLARKE, Esq., F.L.S.

3. "Remarks on a Hebridean Example of the Lesser Whitethroat (*Sylvia curruca*, Linn.); with Exhibition of Specimen." By W. EAGLE CLARKE, Esq., F.L.S.

4. "On the Genesis of some Scottish Minerals." Part II. By J. G. GOODCHILD, Esq., F.G.S.

Wednesday, 15th March 1899.—BENJ. N. PEACH, Esq., F.R.S., F.G.S., President, in the Chair.

The following gentlemen were elected Ordinary Fellows of the Society: Magnus Spence, Esq.; Charles Heslop, Esq.; Professor W. Richard Davis.

The following communications were read;

1. **"Results of Meteorological Observations taken in Edinburgh during 1898." By R. C. MOSSMAN, Esq., F.R.S.E., F.R.Met.Soc.**
2. **"Exhibition of some Australian Animals, with Remarks on their Habits." By GREGG WILSON, Esq., Ph.D.**
3. **"On the Genesis of some Scottish Minerals." Part III. By J. G. GOODCHILD, Esq., F.G.S.**

Wednesday, 19th April 1899.—BENJ. N. PEACH, Esq., F.R.S., F.G.S., President, in the Chair.

The following communications were read:

1. "Additional Notes on the Fossil Fishes of the Upper Old Red Sandstone of the Moray Firth Area." No. II. By R. H. TRAQUAIR, Esq., M.D., LL.D., F.R.S.
2. "On a White Phase of Plumage in the Iceland Gull (*Larus leucopterus*), with Exhibition of Specimen." By W. EAGLE CLARKE, Esq., F.L.S.
3. "On Some Insect Pests of the Tea Plant, with Exhibition of Specimens." By R. STEWART MACDOUGALL, Esq., M.A., D.Sc.
4. "On the Metamorphosis of *Rhizophagus depressus*." By R. STEWART MACDOUGALL, Esq., M.A., D.Sc.
5. "Exhibition of a Natural Cast of the Lower Jaw of a Horse, the Bone being replaced by Peat." By JAMES SIMPSON, Esq.
6. "Exhibition of Living Egyptian Beetles" (*Pimelia* sp. and *Teutyria* sp.). By WM. S. BRUCE, Esq.
7. "Some Further Edinburgh Collembola." By G. H. CARPENTER, Esq., B.Sc., and WILLIAM EVANS, Esq., F.R.S.E.
8. "On the Genesis of Some Scottish Minerals." Part IV. By J. G. GOODCHILD, Esq., F.G.S.

SESSION XXIX.

Wednesday, 15th November 1899.—BENJ. N. PEACH, Esq., F.R.S., F.G.S., President, in the Chair.

The following gentleman was elected an Ordinary Fellow of the Society: Andrew G. Stenhouse, Esq.

Dr MUNRO, Vice-President, delivered the Opening Address, entitled, "Stray Thoughts on the Theory of Organic Evolution, more especially as applied to Man."

Wednesday, 20th December 1899.—BENJ. N. PEACH, Esq., F.R.S., F.G.S., President, in the Chair.

The following gentlemen were elected Ordinary Fellows of the Society: Owen St John Moses, Esq., M.B., C.M.; Robert Godfrey, Esq., M.A.

The following Office-Bearers for the Session were elected:

President—B. N. PEACH, F.R.S., F.G.S.

Vice-Presidents—ROBERT MUNRO, M.A., M.D., F.R.S.E.; J. S. FLETT, M.B., B.Sc.; DAVID HEPBURN, M.D., F.R.S.E.

Secretary—R. H. TRAQUAIR, M.D., LL.D., F.R.S.

Assistant-Secretary—W. S. BRUCE, F.R.S.G.S.

Treasurer—GEORGE LISLE, F.F.A., C.A.

Librarian—J. STUART THOMSON.

Councillors—Professor J. COSSAR EWART, F.R.S.; Lieut.-Colonel R. G. WARDLAW RAMSAY; T. B. SPRAGUE, LL.D.; JAMES DAVIDSON, Esq.; J. ARTHUR THOMSON, M.A., F.R.S.E.; WILLIAM EVANS, F.R.S.E.; GREGG WILSON, M.A., D.Sc.; W. EAGLE CLARKE, F.L.S.; R. KIDSTON, F.R.S.E., F.G.S.; R. TURNBULL, B.Sc.; LIONEL W. HINXMAN, B.A.; ROBERT C. MOSSMAN, F.R.S.E.

The Secretary, Treasurer, and Librarian submitted their Annual Reports.

The following communications were read:

1. "Preliminary Summary of the Fauna of Franz Josef Land." By WILLIAM S. BRUCE, Esq., F.R.S.G.S., and T. N. JOHNSTON, Esq., M.B., C.M. With Limelight Illustrations.
2. "On a Skull of Risso's Grampus (*Grampus griseus*, Cuv.) obtained off the Isle of May." By the SECRETARY.
3. "Exhibition, with Remarks, of the Eggs of *Emberiza ciopsis* from Inno Fuji, Japan, and of *Emberiza* sp. from Inuo Mina, Japan." By J. B. DOBBIE, Esq., F.R.S.E.
4. Dr HEPBURN exhibited, with Remarks, an improved form of Craniometer and a new Osteometric Board.
5. Dr MUNRO exhibited, on behalf of Mr MORRIS, Stirling, a portion of a Bovine Skull found in a street cutting in Stirling.

Wednesday, 17th January 1900.—BENJ. N. PEACH, Esq., F.R.S., F.G.S., President, in the Chair.

The following gentlemen were elected Ordinary Fellows of the Society: Professor E. A. Schäfer, F.R.S.,; Arthur T. Masterman, Esq., D.Sc.

The following communications were read:

1. "Results of Experiments bearing on Variation." By Professor J. C. EWART, M.D., F.R.S.
2. "Exhibition of a new Index Calculator, an instrument for determining the Indices of Skulls without arithmetical calculation." By DAVID WATERSTON, Esq., M.B., C.M.
3. "Exhibition of Pyritised Fossils from the Lower Devonian Roofing-slate of Gmünden, Germany." By the SECRETARY.

Wednesday, 21st February 1900.—BENJ. N. PEACH, Esq., F.R.S., F.G.S., President, in the Chair.

The following gentlemen were elected Ordinary Fellows of the Society: William L. Macgillivray, Esq.; James Watt, Esq., C.A.

The following communications were read·

1. "Contributions to the Ethnology and Anthropology of the Somali, Abyssinian, Galla, and Shangalla Races." By REGINALD KŒTTLITZ, Esq., M.R.C.S.Eng., L.R.C.P.Ed. Communicated by WM. S. BRUCE, Esq., F.R.S.G.S.
2. "Exhibition of Skulls, Implements, and Insects collected by Dr Kœttlitz." By WM. S. BRUCE, Esq., F.R.S.G.S.
3. "Results of Meteorological Observations taken in Edinburgh during 1899." By R. C. MOSSMAN, Esq., F.R.S.G.S.

Wednesday, 21st March 1900.—BENJ. N. PEACH, Esq., F.R.S., F.G.S., President, in the Chair.

The following communications were read:

1. "Results of Meteorological Observations taken in Edinburgh during 1899." By R. C. MOSSMAN, Esq., F.R.S.E
2. "Notes on the Early Development of *Cribrella oculata* (*Echinaster sanguinolenta*), with Observations on General Asterid Development." By A. T. MASTERMAN, Esq., M.A., D.Sc.
3. "Notes on the Development of Ceratodus—(1) the Lung, (2) the Excretory Organs." By GREGG WILSON, Esq., D.Sc.

Wednesday, 18th April 1900.—BENJ. N. PEACH, Esq., F.R.S., F.G.S., President, in the Chair.

The following gentlemen were elected Honorary Fellows of the Society: Herbert Kynaston, Esq., B.A., F.G.S.; George Sandeman, Esq , M.A.; James Miller, Esq., B.Sc., M.B., Ch.B.

The following communications were read:

1. "On the Dentition of a Young Specimen of Sowerby's Whale (*Mesoplodon bidens*, Sow.)." By Dr TRAQUAIR, F.R.S , and WILLIAM TAYLOR, Esq.
2. "Notes on Mammalian and other Fragmentary Bones from Smoo Cave, Durness, Sutherlandshire." By DAVID HEPBURN, Esq., M.D.
3. "Preliminary List of the *Hymenoptera aculeata* of the Edinburgh District." By WILLIAM EVANS, Esq., F.R.S.E.
4. "Simpler Methods in Crystallography. Part I., Stereograms." By J. G. GOODCHILD, Esq., F.G.S.

SESSION CXXX.

Wednesday, 21st November 1900.—BENJ. N. PEACH, Esq., F.R.S., F.G.S., President, in the Chair.

Mr B. N. PEACH, F.R.S., the retiring President, delivered the Opening Address, entitled "Scottish Palæontology during the last Twenty Years."

Wednesday, 19th December 1900.—BENJ. N. PEACH, Esq., F.R.S., F.G.S., President, in the Chair.

The following gentlemen were elected Ordinary Fellows of the Society: Cecil B. Crampton, Esq., M.B., C.M.; David Tait, Esq.

The following Office-Bearers for the Session were elected:

President—Professor J. COSSAR EWART, M.D., F.R.S.

Vice-Presidents—J. S. FLETT, M.B., B.Sc.; DAVID HEPBURN, M.D., F.R.S.E.; W. S. BRUCE, F.R.S.G.S.

Secretary—R. H. TRAQUAIR, M.D., LL.D., F.R.S.

Assistant-Secretary—GREGG WILSON, M.A., D.Sc.

Treasurer—GEORGE LISLE, F.F.A., C.A.

Librarian—T. N. JOHNSTON, M.B., C.M.

Councillors—J. Arthur Thomson, M.A., F.R.S.E.; William Evans, F.R.S.E.; W. Eagle Clarke, F.L.S.; R. Kidston, F.R.S.E., F.G.S.; R. Turnbull, B.Sc.; Lionel W. Hinxman, B.A.; Robert C. Mossman, F.R.S.E.; Professor E. A. Schäfer, F.R.S.; Richard J. A. Berry, M.D.; David Waterston, M.A., M.B., F.R.C.S.E.; Robert Munro, M.A., M.D., F.R.S.E.; B. N. Peach, F.R.S., F.G.S.

The Secretary, Treasurer, and Librarian submitted their Annual Reports.

The following communications were read:

1. "Zoological Names and Theories of the Malays." By NELSON ANNANDALE, Esq., B.A. Communicated by Dr GREGG WILSON.
2. "Exhibition of Lantern Slides of Photographs of Living Insects, illustrating Protective Resemblance." By the same.
3. "Notes on Fossil Fishes from Eastern Fifeshire." By the SECRETARY.
4. "Exhibition of Bees captured by *Aranjia albens.*" By R. STEWART MACDOUGALL, Esq., D.Sc.

Wednesday, 16th January 1901.—Professor J. COSSAR EWART, M.D., F.R.S., President, in the Chair.

The following gentlemen were elected Ordinary Fellows of the Society: Nelson Annandale, Esq., B.A.; J. H. Ashworth, Esq., D.Sc.; F. H. A. Marshall, Esq., B.A.

The following communications were read:

1. "Notes on Fossil Fishes from Eastern Fifeshire." By the SECRETARY.

2 "Lantern and Microscopical Demonstration on the True Cœcal Apex, or the Vermiform Appendix." By Dr RICHARD J. A. BERRY, F.R.S.E.

Wednesday, 20th February 1901.—Professor J. COSSAR EWART, M.D., F.R.S., President, in the Chair.

The following gentlemen were elected Ordinary Fellows of the Society: Thomas Hedley, Esq., B.A., LL.B.; John Paul, Esq.

The following communications were read:

1. "Developmental Changes in the Human Skeleton from the point of view of Anthropology, with Lantern Illustrations." By DAVID WATERSTON, Esq., M.D.
2. "Remarks on supposed New Zebra from the Congo." By Professor J. C. EWART, M.D., F.R.S.
3. "Note on the Development of the Coracoid of the Horse." By O C. BRADLEY, Esq., M.B., Ch.B.
4. "Note on the Habits of *Galeopithecus volans.*" By NELSON ANNANDALE, Esq., B.A.

Wednesday, 20th March 1901.—Professor J. COSSAR EWART, M.D., F.R.S., President, in the Chair.

The following gentleman was elected an Ordinary Fellow of the Society: Colonel J. Campbell.

The following communications were read:

1. "Suggestions on Extinction of Species." By CECIL B. CRAMPTON, Esq., M.B., C.M.
2. "Results of Meteorological Observations taken in Edinburgh during the Year 1900." By R. C. MOSSMAN, Esq., F.R.S.E.

Wednesday, 17th April 1901.—Professor J. COSSAR EWART, M.D., F.R.S., President, in the Chair.

The following communications were read:

1. "Obituary Notice of the late Mr James Bennie." By J. G. GOODCHILD, Esq., F.G.S.
2. "Further Notes on the Fauna of the Upper Old Red Sandstone of the Moray Firth Area." By the SECRETARY.
3. "The *Hymenoptera aculeata* of the Edinburgh District." By WILLIAM EVANS, Esq., F.R.S.E. With Exhibition of Specimens.
4. "Simpler Methods in Crystallography." Concluding Part. By J. G. GOODCHILD, Esq., F.G.S

LIST OF SOCIETIES WHICH RECEIVE THE SOCIETY'S "PROCEEDINGS."

Those Institutions from which Publications have been received in return are indicated by an asterisk.

ENGLAND.

BIRMINGHAM, . .	*Philosophical Society, King Edward's Grammar School.
Do. . .	*Natural History Society, Sir Josiah Mason's College.
CAMBRIDGE, . .	*Philosophical Society.
Do. . .	University Library.
CIRENCESTER, .	*Editor of the *Agricultural Students' Gazette.*
DURHAM, . .	University Library.
HALIFAX, . .	*Yorkshire Geological and Polytechnic Society.
LEEDS, . . .	*The Conchological Society of Great Britain and Ireland.
LIVERPOOL, . .	*Biological Society, University College.
Do. . .	*Literary and Philosophical Society.
Do. . .	*Engineering Society, Royal Institution.
LONDON, . .	British Museum Library.
Do. . .	*British (Natural History) Museum, South Kensington.
Do. . .	*Royal Society, Burlington House, Piccadilly, W.
Do. . .	Chemical Society, Burlington House, Piccadilly, W.
Do. . .	*Geological Society, Burlington House, Piccadilly, W.
Do. . .	*Linnean Society, Burlington House, Piccadilly, W.
Do . .	*Royal Microscopical Society, King's College.
Do. . .	Museum of Economic Geology, Jermyn Street.
Do. . .	Editor of *Nature*, 29 Bedford Street, Covent Garden.
Do. . .	*Zoological Society, Hanover Square.
Do. . .	*Geologists' Association, University College, W.C.
MANCHESTER, .	*Geological Society, 36 George Street.
Do. . .	*Literary and Philosophical Society, 36 George Street.
Do. . .	The Owens College.
NORWICH, . .	*Norfolk and Norwich Naturalists' Society, The Museum.
OXFORD, . .	The Bodleian Library.
TRURO, . .	*Royal Institution of Cornwall.
WATFORD, . .	*Hertfordshire Natural History Society and Field Club.

SCOTLAND.

ABERDEEN, . .	University Library.
COCKBURNSPATH, .	*Berwickshire Naturalists' Field Club, Old Cambus.
EDINBURGH, . .	Advocates' Library.
Do. . .	University Library.
Do. . .	*Royal Society.
Do. . .	Royal Medical Society.

EDINBURGH, . .	*Royal Scottish Society of Arts.
Do. . .	*Royal Scottish Geographical Society.
Do. . .	*Botanical Society.
Do. . .	*Highland and Agricultural Society.
Do. . .	*Geological Society.
GLASGOW, . .	*Philosophical Society.
Do. . .	*Natural History Society.
Do. . .	*Geological Society.
Do. . .	*Andersonian Society.
Do. . .	University Library.
PERTH, . . .	Perthshire Society of Natural History.
ST ANDREWS, . .	University Library.

IRELAND.

BELFAST, . .	Natural History and Philosophical Society.
DUBLIN, . .	*Royal Irish Academy.
Do. . .	*Royal Dublin Society.
Do. . .	*Royal Geological Society of Ireland.

HOLLAND.

AMSTERDAM, . .	*De Koninklijke Akademie van Wetenschappen.
LEYDEN, . .	*Museum van Naturlijke Histoire.
UTRECHT, . .	Provinciaal Genootschap an Kunsten en Wetenschappen.

SWITZERLAND.

BASLE, . . .	*Die Naturforschende Gesellschaft.
BERN, . . .	*Allgemeine Schweizerische Gesellschaft für die gesammten Naturwissenschaften.
Do. . . .	*Die Naturforschende Gesellschaft.
GENEVA, . .	*Société de Physique et d'Histoire Naturelle.
NEUFCHATEL, .	*Société des Sciences Naturelles.
ZÜRICH, . . .	*Die Naturforschende Gesellschaft.

GERMANY.

BERLIN, . . .	*Königliche Akademie der Wissenschaften.
Do. . . .	*Deutsche Geologische Gesellschaft.
Do. . . .	*Gesellschaft Naturforschender Freunde.
BONN, . . .	*Naturhistorischer Verein der preussischen Rheinlande Westfalens, und des Reg.-Bezirks Osnabrück.
BREMEN, . .	*Verein für Naturwissenschaft.
BRESLAU, . .	*Schlesische Gesellschaft für Vaterländische Cultur.
BRUNSWICK, . .	*Naturwissenschaftlicher Verein.
DRESDEN, . .	Königliche Sammlungen für Kunst und Wissenschaft.
Do. . .	*Der Verein für Erdkunde.
ELBERFELD, . .	*Naturwissenschaftlicher Verein.
ERLANGEN, . .	University Library.
FRANKFORT-ON-MAIN,	*Senckenbergische Naturforschende Gesellschaft.
Do.	*Deutsche Malakozoologische Gesellschaft, Dr Kobelt, Schwanheim.
FREIBURG, i. B., .	Die Naturforschende Gesellschaft.
GÖTTINGEN, . .	*Königliche Gesellschaft der Wissenschaften.
HALLE, . . .	*Kaiserliche Akademie der Naturforscher.

JENA, . . .	Medicinisch-naturwissenschaftliche Gesellschaft.
LEIPZIG, . . .	*Königliche Sächsische Gesellschaft der Wissenschaften.
Do. . . .	Naturforschende Gesellschaft.
Do. . . .	Editor of the *Zoologischer Anzeiger.*
MUNICH, . .	*Königliche Baierische Akademie der Wissenschaften.
STUTTGART, . .	*Verein für Vaterländische Cultur in Württemberg.
WÜRZBURG, . .	*Physikalisch-medicinische Gesellschaft.

AUSTRIA.

AGRAM, . . .	*Societas Croatica Historico-naturalis.
HERMANNSTADT, .	*Siebenbürgischer Verein für Naturwissenschaft.
PRAGUE, . .	Königliche-böhmische Gesellschaft der Wissenschaften.
TRIESTE, . .	Società Adriatica di Scienze Naturali.
VIENNA, . .	*K.k. zoologisch-botanische Gesellschaft.
Do. . .	*K.k. Naturhistorisches Hof-Museum.

ITALY.

BOLOGNA . .	*Accademia delle Scienze dell' Istituto.
MILAN, . . .	*Reale Istituto Lombardo di Scienze, Lettere ed Arti.
Do. . . .	Società Italiana di Scienze Naturali.
MODENA, . .	Società dei Naturalisti.
NAPLES, . .	Editor of the *Zoologischer Jahresbericht*, Zoological Station.
PADUA, . . .	*Società Veneto-Trentina di Scienze Naturali residente in Padova.
ROME, . . .	*Reale Accademia dei Lincei.
TURIN, . . .	*Reale Accademia delle Scienze.

SPAIN.

MADRID, . .	*Real Academia de Ciencias exactas, fisicas e naturales.
Do. . .	Sociedad española de Historia natural.

PORTUGAL.

COIMBRA, . .	Bibliothèque de l'Université.
LISBON, . . .	*Academia Real das Sciencias.

FRANCE.

BORDEAUX, . .	La Société Linnéenne.
CAEN, . . .	Société Linnéenne de Normandie.
CHERBOURG, . .	*Société Nationale des Sciences Naturelles.
PARIS, . . .	*Académie des Sciences de l'Institut.
Do. . . .	*Société Géologique de France, Rue des grands Augustins, 7.
Do. . . .	*Société Zoologique de France, Rue des grands Augustins, 7.
Do. . . .	Société de Biologie.
Do. . . .	École des Mines.

BELGIUM.

BRUSSELS, . .	*Académie Royale des Sciences, des Lettres, et des beaux Arts.
Do. . .	*Société Royale Malacologique de Belgique.
Do. . .	*Société Belge de Microscopie.

SCANDINAVIA.

BERGEN, . .	*The Museum.
CHRISTIANIA, .	*Den Naturhistoriske Forening.
Do. . .	Universitets Bibliothek.
COPENHAGEN, .	*Kongelige Danske Videnskabernes Selskab.
Do. . .	*Naturhistoriske Forening.
STOCKHOLM, . .	*Kongliga Svenska Vetenskaps-Akademie.
UPSALA, . .	*Kongliga Vetenskaps-Societeten.
Do. . .	*Observatoire Météorologique.

RUSSIA.

DORPAT, . .	*Naturforscher Gesellschaft.
KIEV, . . .	*Natural History Society.
MOSCOW, . .	*Société Impériale des Naturalistes.
ST PETERSBURG, .	*Académie Impériale des Sciences.
Do. . .	*Imperial Botanic Garden.

AMERICA.

UNITED STATES.

ALBANY, N. Y., .	*New York State Library.
BALTIMORE, . .	*Johns-Hopkins University Library.
BOSTON, . .	*American Academy of Arts and Sciences.
Do. . .	*Society of Natural History.
BROOKVILLE, IND.,	*Brookville Society of Natural History.
CAMBRIDGE, MASS.,	*Harvard University Library.
Do.	*Museum of Comparative Zoology.
CHICAGO, . .	*Academy of Sciences.
CINCINNATI, . .	*Society of Natural History.
NEWHAVEN, CONN.,	*Connecticut Academy of Arts and Sciences.
Do.	Yale College Library.
NEW YORK, . .	*New York Academy of Sciences.
OHIO, . . .	*Mechanics Institute.
PHILADELPHIA, .	*Academy of Natural Sciences.
Do. .	*Wagner Free Institute.
SAN FRANCISCO, .	*California Academy of Sciences.
ST LOUIS, . .	*Academy of Sciences.
WASHINGTON, .	*Smithsonian Institute.
Do. . .	Philosophical Society.
Do. . .	*United States National Museum.
Do. . .	*United States Geological Survey.
Do. . .	*United States Commissioner of Fish and Fisheries.
WISCONSIN, . .	*Academy of Sciences, Arts, and Letters.

MEXICO.

MEXICO, . .	*Ministerio de Fomento de la Republica, Osservatorio Meteorologico.
Do. . .	*Sociedad Cientifica, "Antonio Alzate," Osservatorio Meteorologico Central.

CANADA.

HAMILTON, . .	*The Hamilton Association.
KINGSTON, . .	*Queen's University.

MANITOBA, . .	*Historical and Scientific Society, Winnipeg.
MONTREAL, . .	*The Natural History Society.
OTTAWA, . .	*Canadian Geological Survey.
Do. . .	*Royal Society of Canada.
TORONTO, . .	*The Canadian Institute.

NOVA SCOTIA.

HALIFAX, . .	*Nova Scotia Institute of Natural Science.

BRAZIL.

RIO DE JANEIRO, .	Museu Nacional.

AFRICA.

CAPE TOWN, . .	South African Philosophical Society.

ASIA.

BATAVIA. . .	*Koninklijke Natuurkundige Vereeniging in Nederlandsch Indie.
CALCUTTA, . .	Royal Asiatic Society of Bengal.
SHANGHAI, . .	*China Branch of the Asiatic Society.
TOKIO, JAPAN, .	*Imperial University of Japan.

AUSTRALASIA.

ADELAIDE, . .	*Royal Society of South Australia.
MELBOURNE, . .	*Royal Society of Victoria.
SYDNEY, . .	*Royal Society of New South Wales.
Do. . .	*The Australian Museum.
Do. . .	*Linnean Society of New South Wales.
WELLINGTON, .	*New Zealand Institute.

LIST OF FELLOWS.

*Those marked * are Life Members.*

Date of Election.

1895. Aitken, E. H., Salt Department, Bombay.
1893. Alexander, John, M.D., L.R.C.P., L.R.C.S., D.P.H., Wick.
1872. Anderson, James, Ormidale, East Suffolk Road.
1901. Annandale, Nelson, B.A., 34 Charlotte Square.
1884. Armitage, J. A., B.A., 28 Waterloo Road South, Wolverhampton.
1902. Ashworth, J. H., D.Sc., Natural History Department, University.
1893. Bailey, Lieut.-Colonel Fred., (*late*) R.E., F.R.G.S., F.R.S.E., 7 Drummond Place.
1885. Barbour, A. H. F., M.A., B.Sc., M.D., 4 Charlotte Square.
1884. Beaumont, Alfred, The Red Cottage, Blackheath Park, London, S.E.
1880. *Beddard, Frank E., M.A., F.R.S., Zoological Gardens, London.
1896. Beesly, Lewis, University Union, Park Place.
1897. Berry, Richard J. A., M.D., 4 Howard Place.
1881. *Berry, W., Tayfield, Newport, Fife.
1898. Bisset, James, M.A., F.L.S., F.G.S., 9 Greenhill Park.
1891. Bosse, Fr., Edinburgh Geographical Institute, Park Road.
1892. Bowhill, Thomas, F.R.C.V.S.
1893. Bradley, O. C., M.B., Ch.B., Royal (Dick) Veterinary College.
1897. Brown, Campbell, M.A., 1 Dick Place.
1876. Brown, J. A. Harvie-, F.Z.S., F.R.S.E., Dunipace House, Larbert, N.B.
1891. Brown, Richard, C.A., 23 St Andrew Square.
1876. *Bruce, W. P., Kinleith Mill, Currie.
1894. Bruce, W. S., 11 Mount Pleasant, Joppa.
1885. Buckley, T. E., B.A., F.Z.S., Rossal, Inverness.
1894. Burrage, J. H., B.A.(Oxon.), Royal Botanic Garden.
1885. Burt, Robert F., M.B., 124 Stroud Green Road, Finsbury Park, London, N.
1902. Cameron, John, M.B., Ch.B., M.R.C.S.Eng., Anatomy Department, University, St Andrews.
1901. Campbell, Colonel J., Governor H.M. Prison, 30 Waterloo Place.
1893. Campbell, Kenneth Findlater, C.E., Hon.M.Inst.C.E., M.S.I., Town Hall, Huddersfield.
1892. Carlier, Edmond W., B.Sc., M.D., The Mason University, Birmingham.
1876. *Carmichael, Sir T. D. Gibson, Bart., Castlecraig, Dolphinton.
1858. Carruthers, W., F.R.S., British Museum, London.

Date of Election.

1888. Clarke, W. Eagle, F.L.S., Museum of Science and Art.
1895. *Clough, C. T., M.A., Geological Survey, George IV. Bridge.
1893. Coates, H., F.R.S.E., Pitcullen House, Perth.
1881. Cook, C., W.S., 11 Belgrave Crescent.
1887. *Corke, H. C., F.R.S., 178 High Street, Southampton.
1902. Cowan, Francis, Westerlea, Murrayfield.
1897. Craig, E. H. Cunningham, B.A., F.G.S., H.M. Geological Survey, George IV. Bridge.
1900. *Crampton, Cecil B., M.B.C.M., Geological Survey Office, George IV. Bridge.
1897. *Crawford, Francis C., 19 Royal Terrace.
1898. Crawford, John, M.B.C.M., 8 Pentland Terrace.
1874. Crawford, W. C., M.A., 1 Lockharton Gardens, Colinton Road.
1877. *Dalgleish, J. J., Brankston Grange, Bogside Station, Stirling.
1898. Davidson, James, 32 Drumsheugh Gardens.
1899. Davis, Professor W. Richard, 4 Melbourne Place, Swansea, S. Wales.
1894. Day, T. Cuthbert, F.C.S., 36 Hillside Crescent.
1895. Dobbie, Rev. G. S., M.A., 2 Hailes Street.
1894. Dobbie, James Bell, 2 Hailes Street.
1893. Donald, Charles W., M.B., C.M., Konsgarth, Braid Road.
1895. Douglas, William, 10 Castle Street.
1889. Drieberg, Principal C., Agricultural College, Colombo, Ceylon.
1880. Drummond, W., S.S.C., 4 Learmonth Terrace.
1886. Duncan, James, Balfour, Brechin.
1885. Duncan, J. Barker, W.S., 6 Hill Street.
1864. *Duns, Professor, D.D., F.R.S.E., 14 Greenhill Place.
1902. Dunstan, Professor John, M.R.C.V.S., Royal (Dick) Veterinary College.
1888. Edington, Alexander, M.B., C.M., Bacteriological Laboratory, Cape Town, South Africa.
1889. Elsworth, R. C., M.B., C.M., St Helen's Road, Swansea.
1880. Evans, Wm., F.F.A., F.R.S.E., 38 Morningside Park.
1883. Ewart, Professor Cossar, M.D., F.R.S., The University.
1901. Falconer, J. D., B.Sc., Heriot-Watt College.
1902. Farquharson, David A., M.B.C.M., 29 George Square.
1884. *Ferguson, James A. E., M.B., Public Lunatic Asylum, Berbice, British Guiana.
1885. Ferguson, James Haig, M.D., F.R.C.P.E., 25 Rutland Street.
1895. Flett, John Smith, M.B., D.Sc., Museum of Practical Geology, Jermyn Street, London.
1883. Gibson, E., 1 Eglinton Crescent.
1881. Gibson, J., Ph.D., F.R.S.E., 20 George Square.
1880. Glover, J., S.S.C., 1 Hill Street.
1899. Godfrey, Robert, M.A., 46 Cumberland Street.
1889. Goodchild, J. G., F.Z.S., F.G.S., Museum of Science and Art.
1877. Grieve, S., 21 Queen's Crescent.
1886. Grieve, Symington, 11 Lauder Road.
1893. Grimshaw, Percy H., F.E.S., Museum of Science and Art.

Date of Election.

1898. Gunn, Wm., F.G.S., H.M. Geological Survey, 22 Claremont Crescent.
1893. *Guppy, H. B., M.B., F.R.S.E., E.M.A., 21 Henlease Gardens, Westbury, Bristol.
1899. Hay, Wm. Peach, M.B., C.M., Lincoln Road, Peterborough.
1883. Henderson, Professor, M.B., F.L.S., Christian College, Madras.
1883. Hepburn, David, M.D., The University.
1899. Heslop, Charles, Lothian Vale, Holyrood.
1884. Hinxman, Lionel, B.A., Geological Survey, George IV. Bridge.
1878. *Horne, J., F.G.S., LL.D., Geological Survey, George IV. Bridge.
1883. Hoyle, W. E., M.A., F.R.S.E., Owens College, Manchester.
1880. Hunter, James, F.R.C.S.E., F.R.A.S., Rosetta, Liberton.
1895. Johnston, Surgeon-Major Henry Halcro, D.Sc., M.D., C.M., F.L.S., 1 Great Wellington Street, Leith.
1898. Johnston, T. Nicol, M.B., C.M., Corstorphine House, Corstorphine.
1894. Johnstone, Lieut. George, R.N.R., F.R.S.G.S., British India Steam Navigation Co., 16 Strand Road, Calcutta.
1886. Kelso, J. E. H., M.B., C.M., Elmgrove, Southsea, Hants.
1869. *Kennedy, Rev. J., M.A., B.D., 9 Hartington Place.
1892. Kerr, J. Graham, M.A., Christ's College, Cambridge.
1878. Kidston, Robert, F.G.S., F.R.S.E., 12 Clarendon Place, Stirling.
1893. Knott, Professor Cargill G., D.Sc., F.R.S.E., 42 Upper Gray Street.
1900. Kynaston, Herbert, B.A., F.G.S., Geological Survey Office, George IV. Bridge.
1890. Laidlaw, T. G., 8 Morningside Road.
1890. Laing, J. H. A., M.B., C.M., 11 Melville Street.
1884. Laurie, Professor Malcolm, D.Sc., St Mungo's College, Glasgow.
1898. Lee, O. A. J., 58 Manor Place.
1902. *Leigh, J. Hamilton, F.L.S., F.Z.S., Matchams Park, Ringwood, Hants.
1886. Lisle, George, C.A., F.F.A., 5 N. St David Street, *Treasurer*.
1861. Logan, A., Register House.
1878. Macconochie, A., Geological Survey, George IV. Bridge.
1886. M'Cracken, Professor, Crewe.
1882. *M'Donald, L. M., Skaebost, Skye.
1896. *MacDougall, R. Stewart, M.A., D.Sc., 13 Archibald Place.
1900. M'Gillivray, W. L., Eoligary, Barra.
1893. Mackay, Alexander, Solicitor, Bank of Scotland, Thurso.
1878. Maclauchlan, J., Albert Institute, Dundee.
1882. M'Vean, C. A., C.E., Killiemore House, Pennyghael, Isle of Mull, Oban.
1886. MacWatt, Major R. C., M.A., M.B., c/o King, King, & Co., Bombay.
1894. Marr, Thomas R., 6 Russel Place, Woolwich.
1901. Marshall, F. H. A., B.A., 4 Bernard Terrace.
1900. Masterman, Arthur T., D.Sc., New Medical School, Bristo Street.
1889. Millar, Robert C., C.A., 30 York Place.
1898. Miller, Hugh, F.Z.S., Zoological Laboratory, Hill Place.
1898. Morton, Alexander, B.A., c/o Mrs M'Gregor, 17 Lutton Place.
1898. Morton, Kenneth J., F.E.S., 13 Blackford Road.
1899. Moses, Owen St John, M.B., C.M., 11 Argyll Place.

Date of Election.

1890. Mossman, R. C., F.R.Met.S., F.R.S.E., 10 Blacket Place.
1895. Munro, Robert, M.A., M.D., LL.D., F.R.S.E., F.S.A.(Scot.), 48 Manor Place.
1882. Murdoch, J. B., Capelrig, Mearns, Renfrewshire.
1881. Murdoch, T. Burn, M.B., C.M., 14 Charlotte Square.
1874. Murray, D. R., M.B., C.M., 41 Albany Street, Leith.
1877. Murray, Sir John, K.C.B., Ph.D., LL.D., F.L.S., F.R.S.E., Challenger Lodge, Wardie.
1884. Murray, R. Milne, M.A., M.B., 11 Chester Street.
1889. Musgrove, Professor James, M.D., University, St Andrews.
1890. Nimmo, Alexander, M.A., Westbank, Falkirk.
1887. Norman, Rev. Canon, M.A., D.C.L., The Red House, Berkhamstead, Herts.
1887. Oliver, John S., 12 Greenhill Park.
1886. *Panton, George A., F.R.S.E., 73 Westfield Road, Edgbaston, Birmingham.
1893. Parkinson, Thos. Wright, M.B., C.M., Brechin.
1870. Peach, B. N., F.G.S., F.R.S., Geological Survey, George IV. Bridge.
1898. Peach, Charles W., M.B., C.M., 86 Findhorn Place.
1891. Pentland, Young J., 5 Bruntsfield Terrace.
1898. Porter, Charles, M.B., C.M., 5 Roxburgh Street
1879. Pullar, R. D., Brahan, Perth.
1889. Purvis, G. Carrington, B.Sc., M.D., Bacteriological Institute, Grahamstown, Cape Colony.
1885. Raeburn, Harold, 22 Castle Terrace.
1881. *Ramsay, Lieut.-Col. Wardlaw, Whitehill, Rosewell, Midlothian.
1861. *Robertson, T., c/o J. Nisbet & Co., 21 Berners Street, London, W.
1883. Robertson, W. W., Wardie Bank.
1894. Roebuck, W. Denison, F.L.S., 259 Hyde Park Road, Leeds.
1890. Rogerson, John J., M.A., LL.D., 3 Abbotsford Park.
1898. Russell, David, jun., Cadham, Markinch.
1887. Russell, William, M.D., F.R.C.P.E., 3 Walker Street.
1900. Sandeman, George, M.A., The Croft, Colinton.
1900. Schäfer, Professor E. A., F.R.S., The University.
1889. Scott, Thomas, F.L.S., 3 Menzies Road, Torry, Aberdeen.
1902. Semple, Andrew, M.D., Deputy Surgeon-General, 10 Forres Street.
1894. Simpson, D. R., Fernbank, Wick.
1902. Simpson, J. Y., D.Sc., F.R.S.E., 52 Queen Street.
1886. Somerville, Professor Wm., M.A., B.Sc., F.R.S.E., F.L.S., 4 Whitehall Place, London, S.W.
1899. Spence, Magnus, Public School, Deerness, by Kirkwall, Orkney.
1880. Sprague, T. Bond, M.A., LL.D., F.R.S.E., 29 Buckingham Terrace.
1896. Steele, A. B., 41 Regent Street, Portobello.
1899. Stenhouse, Andrew G., 191 Newhaven Road, Leith.
1882. Stewart, R., S.S.C., 7 E. Claremont Street.
1898. Tagg, H. Frank, Royal Botanic Garden.
1900. *Tait, David, Geological Survey Office, George IV. Bridge.
1881. Tanner, S. T., 24 Sussex Place, Regent's Park, London.

Date of Election.

Date of Election.	
	*Taylor, A., 11 Lutton Place.
1894.	Taylor, William, Lhanbryde, Elgin.
1893.	Terras, James A., B.Sc., 40 Findhorn Place.
1887.	Thomson, Professor J. Arthur, M.A., F.R.S.E., The University, Aberdeen.
1892.	Thomson, James Stuart, Plymouth.
1876.	*Thomson, John.
1885.	Tomlinson, Henry T., M.B., C.M., Coton Road, Nuneaton.
1859.	Traquair, R. H., M.D., LL.D., F.R.S., Museum of Science and Art, *Secretary*.
1899.	Turnbull, Robert, B.Sc., Department of Agriculture, Dublin.
1858.	*Turner, Professor Sir Wm., K.C.B., LL.D., F.R.S., 6 Eton Terrace.
1895.	Vallance, David J., Museum of Science and Art.
1901.	Waddell, James Alex., 12 Kew Terrace, Glasgow.
1882.	Wallace, Professor R., The University.
1898.	Waterston, David, M.A., M.D., F.R C.S.E., Anatomy Department, The University.
1900.	Watt, James, C.A., 37 George Street.
1884.	Webster, A. D., M.D., 20 Newington Road
1894.	Whitaker, J. Ryland, B.A., M.B.(Lond.), L.R.C.P.E., 27 Castle Terrace.
1884.	White, J. Martin, Balruddery, Dundee.
1888.	White, Philip J., M.B., C.M., University College, Bangor.
1890.	Williams, John Robert, M.B., C.M., Ardre, Penmaenmawr.
1895.	Wilson, Gregg, D.Sc., Surgeons' Hall.
1886.	Wood, George E. C., M.B., C.M., Baileyfield, Portobello.
1883.	*Woodhead, Professor G. S., M.D., F.R.S.E., University, Cambridge.
1896.	Yeoman, John B., M.B., Neston, Cheshire.
1881.	Young, F. W., F.C.S., F.R.S.E., 32 Buckingham Terrace, Glasgow.
1898.	Young, J. M'Lauchlan, F.R.C.V.S., The University, Aberdeen.

CORRESPONDING.

Date of Election.	
	Andrew, Rev. J., Newbury, Fifeshire.
1875.	Coughtrey, Millen, M.D., Prof. Anat. and Physiology, University of Otago, New Zealand.
1858.	Duncan, Rev. J., Denholm.
1870.	Fraser, Rev. Samuel, Melbourne.
1871.	Grieve, A. F., Brisbane, Queensland.
1852.	Howden, J. C., M.D., Montrose.
1874.	Joass, Rev. J. M., LL.D., Golspie.
1874.	Jolly, William.
1885.	Lindström, Professor Gustav, Stockholm.
1871.	Macdonald, John, S.S.C., 19 York Place, Edinburgh.
	Mushet, David, Gloucester.
1885.	Nathorst, Professor A. G., Surveyor-General, Geological Survey of Sweden, Stockholm.
1867.	Robb, Rev. Alexander, Old Calabar.

HONORARY.

1857.	Chevrolat, Auguste, Paris.
1865.	Colloredo-Mannsfeldt, Prince, Vienna.
1857.	Dohrn, C. A., Zoological Station, Naples.
1857.	Fairmaire, Léon, Paris.
1883.	Geikie, Sir Archibald (Ord. Memb. 1878), *Olim Præses.*
1895.	Geikie, Professor James, LL.D., D.C.L., F.R.S., The University, Edinburgh.
1857.	Gerstaecker, A., Greifswald.
1857.	Javet, Charles, Paris.
1857.	Kraatz, G., Berlin.
1886.	Lacaze-Duthiers, H. de, Paris.
1888.	Lankester, Professor E. R., F.R.S., British Museum.
1893.	Lapworth, Professor, F.R.S., Mason College, Birmingham.
1869.	Lütken, Chr., University Museum, Copenhagen.
1857.	Obert, M., St Petersburg.
1888.	Vines, Sydney H., M.A., F.R.S., Christ's College, Cambridge.

Fellows are requested to intimate change of Address to

DR TRAQUAIR, *Secretary,*

MUSEUM OF SCIENCE AND ART, EDINBURGH.